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THE WESTERN SOCIETY OF MALACOLOGISTS

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Abstracts and papers from the 41st annual meeting of the
Western Society of Malacologists held at the U.S. Geological Survey,
Menlo Park, California, June 5-8, 2008

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ABSTRACTS

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NEW RECORDS OF HOLOPLANKTONIC MOLLUSCS (MOLLUSCA: GASTROPODA) IN THE GULF OF CALIFORNIA

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The holoplanktonic mollusks are the only gastropods that have successfully adapted for the pelagic environment throughout their full life cycles. These are comprehended in four major groups: Heteropods, Pteropods, Gymnostomids, and Nudibranchia. Records of holoplanktonic mollusks in the Gulf of California are almost non-existent (6), and are result of sporadic findings. The first and only systematic study has been made by Seapy & Skoglund (2001) in the Gulf of California, where they recorded 10 species (>50% of previous findings) resulting in 16 species for the Gulf of California. In this work we obtained a total of 49,404 organisms from seven inter-institutional oceanographic surveys in the Gulf of California, collected with oblique Bongo tows, with a 505- μ m mesh net equipped with a flow meter, resulting in 66 species (including nine unidentified taxa); of which 38 are new records (Heteropoda 13 species, Pteropoda 14 species, Gymnostomida 11 species and Nudibranchia 1).

Seapy, R. & Skoglund, C. 2001. First Records of Atlantid Heteropod Mollusks from the Golfo de California: *The Festivus*, v. 33, no. 4, p. 33-44.

BIOGEOGRAPHY OF NORTHEAST PACIFIC OPISTHOBRANCHS: COMPARATIVE FAUNAL PROVINCE STUDIES BETWEEN 34° 23'N AND THE EQUATOR

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In the four marine faunal provinces between Point Conception, California, USA, and Perú there are 398 known (= reported in the literature or in prep. by McLean) species of Opisthobranchia *s.l.* The Cephalaspidea and Doridina Nudibranchia are the most speciose taxa, both overall and in each province: Californian (C), Gulf of California (G), Mexican (M) and Panamic (P).

Numbers of total species present vary among the provinces (C, 214 species; G, 183; M, 158; and P, 217), as do relative proportions of the different taxa.

Latitudinal and longitudinal provincial faunal relationships show varying proportions of shared species among these four provinces and with reported Japanese, circumtropical, Indo-Pacific, and Atlantic-Caribbean registers. Dispersal mechanisms and vicariance events seem primarily controlled by thermal regimes and barriers.

Levels of endemism vary greatly, from highs in P (50 species, 23%, of which 30 are unnamed and 12 are reported only from the Islas Galápagos) and C (32 species, 14.9%, of which 22 are shelled cephalaspideans), to lows in M (10 species, 5.5%) and P (nine species, 5.7%).

Provincial level differences of feeding biogeography (relative % of taxa that prey on select higher-level-taxa organisms) are presented.

A preliminary list of 23 sister species groups indicates latitudinal and longitudinal evolutionary relationships.

MARINE BIODIVERSITY RICHNESS AND RESOURCE USE IN NORTHWEST MÉXICO, WITH THE ROLES OF SCIENCE AND ENVIRONMENTAL EDUCATION, AND A CONSERVATION ETHIC

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The incredible biodiversity of the Sea of Cortez includes almost 4,900 named invertebrate species; this may well be only half of the total number of species occurring in this region. However this biota is in extreme danger, due to human activities. "Pollution from agriculture and urban areas, coastal habitat destruction, uncontrolled eco-friendly tourism, inadequate fisheries regulation and historical over-fishing, and lack of reliable scientific data... have resulted in the near extinction of highly visible species..., and substantial reductions in the Gulf's important commercial shrimp and large fish populations" (Brusca, 2004). This is also true for the Pacific coast of the Baja California peninsula.

The range expansion of *Dosidicus gigas* (Humboldt squid) into the Sea of Cortez and along the coasts of California and the Pacific Northwest during the past 35 years may well be due to multiple synergistic events: global warming, rising sea temperatures, and their occupying niches left vacant by over fishing of their normal predators.

Octopuses, clams (such as *Oppenheimopecten vogdesi*), snails (*Plicopurpura pansa* = *columellaris*), sea stars (*Heliaster kubitiji*), sea cucumbers (*Isostichopus fuscus* and *Parastichopus parvimensis*), and urchins (*Strongylocentrotus franciscanus*) have all suffered population declines from over-collecting.

The ill-planned Escalera Nautica, lacking even a marketing-potential prospectus, is destroying not only natural habitats, but also the physico-biological resources of the very communities it purported that it would benefit. At Santa Rosalita, construction of the dock and breakwater changed water currents, resulting in the loss of over 20 meters of beach sand in front of the community (losing panga-launching sites, and putting homes in danger of falling into the sea). The government took away their legal rights to the land (after more than 40 years of being there), and is giving the Cooperative's fishing permits to outsiders.

In contrast, the 10 Mexican cooperatives between Punta Abreojos and Isla Cedros maintain a sustainable harvest of spiny lobster (*Panulirus interruptus*).

Some over-exploited commercial species depend heavily upon mariculture for commercial harvests: abalone (*Haliotis* spp.), mano de león (*Nodipecten subnodosus*), Catarina scallop (*Argopecten ventricosus*), and pearl oysters, among others.

Sustainable use of earth depends upon a multi-layered interrelationship among all components (human, biological and physical) of an ecosystem. Environmental and community groups and individuals, the Mexican government, and the United Nations have successfully established national parks, Reservas de la Biósfera (Islas del Golfo de California, Bahía de los Ángeles y Canales de Ballenas y Salsipuedes, and El Vizcaino) and Areas Naturales Protegidas (Valle de los Cirios). Significant portions of the Sea of Cortez were declared a Natural World Heritage Site by UNESCO (2005).

The benign cohabitation of salt processing (by Exportadores de Sal, S.A. de C.V.) and whale and bird watching in Laguna Ojo de Liebre mutually benefits all organisms (including humans and their needs, pleasures and economy). When the telephone poles were replaced between Guerrero Negro and the salt-loading and whale-watching docks, each pole hosting an osprey family's nest was left intact and untouched.

The goals of scientific investigation—discovery, dissemination and application—create a nexus between human cultures within the global ecosystem. There are ethical imperatives to “doing science”: We cannot do bad science. We cannot lie about nor change the results. Nor can we ignore their consequences and not do anything regarding them. Our right to do science depends upon our responsibility of doing it well, benefiting the interrelationships of all our planet's ecosystems.

Important themes of environmental education must be explained clearly and with excellent science to communities and agencies at local, state and federal levels (including ejidal, cooperative, ecotourist, environmental, commercial and governmental), so they can make ecologically sensitive decisions and take appropriate actions. Environmental education and science education should be considered synonymous, with the same process: Observation → Knowledge → Communication → Use for Living Beings → Actions to Do.

Our actions must be done with care and reverence for all ecosystems and their inhabitants, resulting in the preservation, conservation and protection of biodiversity. We are a part of, not apart from, Global Life.

It behooves us to collaborate in teaching an effective conservation ethic for humans and the living waters of not just the Sea of Cortez, but of all seas and lands, as we search for understanding, appreciation and conservation of life's beauty.

Let me propose a Conservation Ethic: “To develop and use a sustainable management plan for life, which conserves, protects and manages Earth's biodiversity for the health and well-being of all members of the Global Ecosystem.”

RIQUEZA DE LA BIODIVERSIDAD MARINA Y USO DE LOS RECURSOS EN EL NOROESTE DE MÉXICO, CON EL PAPEL QUE JUEGA LA CIENCIA Y EDUCACIÓN AMBIENTAL, Y UNA ÉTICA DE CONSERVACIÓN

Hans Bertsch y Rosa del Carmen Campay

La increíble biodiversidad del Mar de Cortés incluye casi 4,900 especies registradas (nombradas) de invertebrados marinos; esta cifra bien podría ser sólo la mitad del total de especies que ocurren en esta región. Sin embargo esta biota se encuentra en extremo peligro debido a las actividades humanas. “La contaminación proveniente de la agricultura y las áreas urbanas, destrucción del hábitat costero, turismo ecológico sin control, reglamentos pesqueros inadecuados y sobre pesca histórica, así como la falta de datos científicos confiables, han resultado casi en la extinción de especies muy visibles... así como reducciones sustanciales en las poblaciones de camarón y de otras especies de importancia comercial en el golfo” (Brusca, 2004). Esto también es cierto para la costa del Pacífico de la península de Baja California.

Durante los últimos 35 años, la expansión del rango de *Dosidicus gigas* (calamar de Humboldt o Diablo Rojo) en el Mar de Cortés y a lo largo de las costas de California y el Pacífico Noroeste, bien puede deberse a múltiples eventos en sinergia: calentamiento global, aumento de temperatura del mar, y ocupar los sitios dejados vacantes por la sobre pesca de sus predadores naturales.

Pulpos, almejas (como *Oppenheimopecten vogdesi*), caracoles (*Plicopurpura pansa* = *columellaris*), estrellas de mar (*Heliaster kubiniji*), pepinos marinos (*Isostichopus fuscus* y *Parastichopus parvimensis*), así como erizos (*Strongylocentrotus franciscanus*), han sufrido todos declinación de sus poblaciones por sobre colección y sobre pesca.

El proyecto de Escalera Náutica, mal concebido y hasta carente de bases mercadotécnicas, no sólo está destruyendo los hábitats naturales, sino los recursos físico-biológicos de las mismas comunidades que debería beneficiar. En Santa Rosalita la construcción de la dársena modificó las corrientes, lo que provocó la pérdida de más de 20 metros de playa frente a la comunidad (no hay lugar para embarcaciones y algunas casas están a punto de caerse); el gobierno detuvo el trámite de tenencia de la tierra (a pesar de más de 40 años de habitación), y están dando permisos de pesca a personas de fuera, que les corresponden a la Cooperativa local.

En contraste, las 10 cooperativas mexicanas ubicadas entre Punta Abreojos e Isla Cedros, mantienen una captura sustentable de langosta (*Panulirus interruptus*).

Algunas especies sobre explotadas dependen mucho de la maricultura para lograr cosechas a escala comercial: adulón, (*Halotis* spp.), mano de león (*Nodipecten subnodosus*), callo Catarina (*Argopecten ventricosus*), y ostras perlíferas, entre otras.

El uso sustentable del planeta depende de una relación entre múltiples niveles de los componentes de un ecosistema (humano, biológico y físico). Los grupos ambientalistas, comunitarios, e individuos, el Gobierno Mexicano y las Naciones Unidas han establecido exitosamente Parques Nacionales, Reservas de la Biosfera (Islas del Golfo de California, Bahía de los Ángeles, Canales de Ballenas y Salsipuedes, y El Vizcaíno) y Áreas Naturales Protegidas (Valle de los Cirios). Porciones muy significativas del Mar de Cortés han sido declaradas Patrimonio Natural de la Humanidad por la UNESCO (2005).

La cohabitación benigna entre procesamiento de sal (por Exportadores de Sal, S.A. de C.V.)

y el avistamiento de ballenas y de aves en Laguna Ojo de Liebre, beneficia mutuamente a todos los organismos (incluyendo a los humanos y sus necesidades, aficiones y economías). Cuando se colocaron postes telefónicos entre Guerrero Negro y los muelles de embarque de sal y del avistamiento de ballenas, se dejó intacto cada poste que albergaba un nido de Gavilán Pescador.

Las metas de la investigación científica —descubrimiento, diseminación y aplicación — crean un nexo entre la cultura humana dentro del ecosistema global. Hay imperativos éticos para “hacer ciencia”: No podemos hacer mala ciencia. No podemos mentir ni cambiar los resultados. Ni podemos ignorar sus consecuencias y no hacer nada al respecto. Nuestro derecho de hacer ciencia depende de nuestra responsabilidad de hacerla bien, en beneficio de las interrelaciones de todos los ecosistemas del planeta.

Los temas importantes de educación ambiental deben explicarse claramente y con excelente ciencia a las comunidades y agencias al nivel local, estatal y federal (incluyendo ejidal, cooperativas, ecoturismo, ambientalistas, comerciales y gubernamentales), para que ellos puedan tomar las decisiones ecológicamente sensatas y tomar las acciones apropiadas. La educación ambiental y la educación en la ciencia deben ser consideradas como sinónimas, con el mismo proceso: Observación —> Conocimiento —> Comunicación —>Uso para los Seres Vivientes —> Acciones a realizar.

Debemos conducir nuestras acciones con cuidado y reverencia para todos los ecosistemas y sus habitantes, de manera que resulten en la preservación, conservación y protección de la biodiversidad. No estamos *aparte de*, sino que somos *parte de* la Vida Global.

Es conveniente que colaboremos en la enseñanza de una ética efectiva de conservación para los humanos y las aguas vivientes, no sólo del Mar de Cortés, sino de todos los mares y tierras, dentro de nuestra búsqueda de entendimiento, aprecio y conservación de la belleza de la vida.

Permítaseme proponer una Ética de Conservación: “Desarrollar y usar un plan sustentable de administración para la vida, que conserve, proteja y dirija la biodiversidad del planeta para la salud y el bienestar de todos los integrantes del Ecosistema Global.

REPRODUCTIVE CYCLE OF *Pinna rugosa* SOWERBY AT SAN IGNACIO LAGOON

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The commercial fisheries of the Pen Shell *Pinna rugosa* Sowerby in Baja California Sur, Mexico, are an established activity despite the lack of basic biological knowledge of the species reproductive cycle. We studied a natural population in San Ignacio Lagoon from March 2000 to April 2003 to develop strategies to establish a sustainable fishery. Monthly, samples of 15 and 7 animals belonging to one size class, were measured and weighed and then sub-sampled to obtained gonadic tissue for histological studies (using paraffin and HE stain for 8 µm slices and resin for 1.5 µm slices, dyed with Toluidine Blue). The reproductive cycle is described using the histological observations and the oocyte sizes measured using photomicroscopy of the paraffin preparations, which were digitalized and measured using the *Image-Pro Plus 5.1* software. The Pen shell is a protandric hermaphrodite, whose reproduction is related to the end of spring and early summer; its

gametogenic cycle begins in the early spring. We describe the evolution of volumetric-condition index and muscle-yield index and we discuss the significance of stopping the fisheries during the reproductive period.

ADVANCES IN THE MOTHER OF PEARL SHELL CARVING WORK FOR THE ESTABLISHMENT OF A FAMILIAL ENTERPRISE IN EL CARDONAL, BAJA CALIFORNIA SUR, MEXICO

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During 2006 we began a mollusk shell handcrafts training program for the community of El Cardonal in the Gulf of California, to aid in the establishment of family business to alleviate poverty. The training program was divided in three steps, a motivation module (2006), to introduce the idea within the community, basic methods for working with the shells, including the use of tools (2007), and finally, shell handcrafts design (2008). All the courses were prepared taking into account the low level of education. We used appropriate teaching techniques and didactic resources to maintain a participative environment among the learners. A group of twelve women was established and named “Mujeres Artesanas del Cardonal.” The results of the first two years let us find economic resources from the Municipality (La Paz, Baja California Sur) for the supply of basic tools. Six of those women developed enough skills to produce shell handcrafts good enough to be sold to local guests in their community. However the handcrafts needed to be unique. The design training helped the women to achieve this, and to identify the features of the community to be included in their work. Now, those twelve women have the knowledge to develop their own family business and have an extra income.

RECRUITMENT DYNAMICS OF THE RAINBOW LIP PEARL OYSTER *Pteria sterna* (GOULD) IN BAHÍA DE LA PAZ, BAJA CALIFORNIA SUR, MÉXICO

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In the Gulf of California, Mexico, the commercial production of pearls from *Pteria sterna* (Gould) relies on juvenile from wild populations. However the quantities of juvenile seed are erratic and show large interannual fluctuations. For instance, during 2006 juvenile density per collector was in the range of 1,000 to 1,500 seeds, while in 2007 the density fell to about 30. This

variability has become a critical problem for the commercial production of pearls since it does not guarantee a consistent and sufficient input of seeds for the production of pearls.

The recruitment process is quite relevant and requires a comprehensive study oriented towards gaining an understanding of the mechanisms that control the production and survival of seed in the wild. We believe that variability in recruitment are dependent on the physiological state of spawners prior to the spawning event, the biotic and abiotic conditions that early life stages encounter during their planktonic phase, and the intra and inter-specific competition for substrate. Here we present our experimental design to approach the problem of the recruitment dynamics of *Pteria sterna* in Bahía de La Paz, Baja California Sur, México. We also present the results obtained during the first phase of this study.

We are relying on a backward particle tracking analysis using a numerical stochastic simulation of currents in Bahía La Paz, a hydrodynamics model, to establish the probable location of the banks of spawners inside the Bay. This model is being adjusted using seed density data from collector placed in 10 locations inside the Bay. Once the banks are located we will proceed to determine the relationship between reproductive effort and energy content of spawners prior to the spawning event using calorimetric and stereological techniques. We are also measuring food availability, substrate space competition, temperature, currents and transparency to establish statistical relationships for the recruitment of seeds in the collectors.

TEN-YEAR COMPARISONS OF MOLLUSCAN ABUNDANCES ON A VERTICAL SUBTIDAL TRANSECT AT THE EDGE OF THE SEA OF CORTEZ, CABO SAN LUCAS, BAJA CALIFORNIA SUR, MÉXICO

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Long-term, detailed comparisons of subtidal plots are rare, but can detect even slow changes in abundances or sizes of animals and plants. In an underwater sanctuary where the Sea of Cortez meets the Pacific at the southern tip of Baja California, at Cabo San Lucas, Kitting established a subtidal photographic transect in 1998, of ~30 cm x 60 cm contiguous quadrats, arranged vertically to a depth of 13 m. In the present study, Carter used Kitting's digital video of the quadrats to compare photographic samples from mid-April, 1998, with our mid-April, 2008 photographic samples. Transparency of the water (horizontal and vertical secchi depth) was measured to be up to 12 meters during the sampling. The vertical rock surface was largely shaded, with little algae and coral. The hypothesis was that some sessile individuals would tend to persist and grow, while other taxa would disappear or increase in abundance. Photographic observations tabulated abundance of larger Mollusca, including numerous "yellow umbrella snail" opisthobranchs (*Tylodina fungina* Gabb), rock scallops (*Crassadoma gigantea* Gray), other mollusks, and other major invertebrates. Although rock scallop shells often were encrusted with variable sponges, hydroids, barnacles, etc., sea fans were aquatic landmarks that helped locate the same individual oysters growing detectably from the previous decade. Detailed comparisons show evidence that diverse mollusks, especially rock scallops, tended to increase in abundance and depth distribution.

TWO PREVIOUSLY UNRECORDED MOLLUSKS DISCOVERED AS HISTORICAL AND INTRODUCED POPULATIONS IN SAN FRANCISCO ESTUARY

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San Francisco Bay contains over 250 invasive species (including many mollusks) documented throughout this estuary. In 2000, we discovered patchy, previously unreported populations of two brackish cochliopid snail species <6mm long, in two restored tidal marshes and a non-tidal pool in southern Suisun Bay, San Francisco Estuary. New morphologic and mtDNA evidence identifies these species as: *Littoridinops monroensis* (Frauenfeld), an estuarine-freshwater species known from coastal habitats from Georgia to Mississippi, and *Tryonia porrecta* Mighels, previously recorded from thermal springs in eastern California, Nevada, Utah, and Sonora (México). *Littoridinops monroensis* was the only cochliopid detected at the non-tidal site. Our northern San Francisco Estuary sampling in 2005 also detected that species 50 km northwest in the estuary and 2007 observations detected it in former salt ponds of southern San Francisco Bay. Our >1.5-m-deep cores at Suisun Bay suggest *T. porrecta* being abundant for >150 years, before widespread European settlement. It was the more abundant species at an older, isolated tidal marsh site, but spatial differences were evident at a tidal marsh with high densities of both species. Both populations have persisted in the estuary for >4 years, surviving widely ranging salinities and hot then occasionally freezing temperatures, although previous records were in warmer climates or thermal springs. MtDNA evidence suggests that *L. monroensis* from the estuary is little differentiated relative to Atlantic coastal populations and probably represents a recent introduction, whereas genetic evidence for *T. porrecta* suggests it is diverged historically but is most closely related to Utah populations. Thus, tiny, inconspicuous species, both introduced and historical species, continue to be discovered in inadequately sampled marshes of this estuary.

UNRAVELING A TANGLE: PHYLOGENETIC ESTIMATE FOR CHITONINA THIELE, 1910 BASED ON 16S RIBOSOMAL DNA

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Chitonida is a well-supported lineage encompassing more than 85% of the about 925 extant chiton (Mollusca: Polyplacophora) species, and usually can be differentiated from living and extinct non-chitonid chitons by a fundamental anatomical difference that is detectable in fossils: the presence of valve slits. These are gaps in the valves' insertion plates, embedded in the girdle, through which bundles of nerves from many of the tegmental sensory esthetes pass on their route around the valves' ends to the ladder-like nervous system of the chiton. Non-chitonid chitons mostly supply sensory innervation to their dorsal valve surface more directly via openings through

the valves' inner surface. Within the Chitonida, the systematics has been controversial but there is emerging agreement, supported by my own results, that Chitonida is subdivided into two lineages: Acanthochitonina Bergenhayn (1930) and Chitonina Thiele (1910). However, there is only modest support for the reciprocal monophyly of these lineages and there has been little resolution within each, particularly so for the 500 recognized species of Chitonina. Here, I present a preliminary phylogenetic analysis of worldwide Chitonina based on 16S ribosomal DNA. Not including outgroups to Chitonina, the analysis is based on sequences from 175 vouchers, representing over 90 species belonging to about 20 genera. The results have generated as many new questions as they have answered but some general conclusions are emerging. As the only sampled exemplars of Callochitonidae Plate (1901), four species of *Callochiton* Gray (1847) group together as the basal lineage within Chitonina and, if further supported, this would have important implications for interpreting recent reports concerning the primitive nature of *Callochiton* gametes in comparison to corresponding derived states in other chitonids. There is general support for conventional genus- to family-level groupings within the remainder of Chitonina but there are also some notable exceptions. *Ischnochiton* Gray (1847), with more than 100 species worldwide, was found to be polyphyletic. Breaking this genus up to reflect the emerging phylogenetic estimates is expected to be an important first step in sorting out Chitonina. For example, *Stenosemus* von Middendorff (1847) has recently been treated as a subgenus of *Ischnochiton* but this analysis instead robustly supports it as a discrete lineage, certainly worthy of generic status. Perhaps the most surprising result is the strong evidence that Chitonidae Rafinesque (1815) is likely biphyletic, with Chitoninae Rafinesque (1815) well separated from Acanthopleurinae Dall (1889) + Toniciinae Pilsbry (1893). This implies that the conventional trait used to unite the family, pectinations on the margin of the insertion plates, might have evolved convergently. These and other results provide some clarification of the complex patterns of morphological variation within Chitonina.

TWO GIANT SPECIES OF *Stenosemus* VON MIDDENDORFF, 1847, FROM SEAMOUNTS OFF SOUTHERN CALIFORNIA

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Geologists at Monterey Bay Aquarium Research Institute, Dave Clague and Lonny Lundsten, have kindly provided us with chitons collected during exploration of seamounts off southern California. We have inferred from morphological and molecular comparisons that there are at least two species of *Stenosemus* present in the material. Both species are much larger-bodied than all currently recognized congeners. Three of the specimens from the Rodriguez Seamount (ca. 34.0° N 121.1° W; 1,213 or 1,412 m) have been compared with *S. stearnsii* (Dall, 1902), whose type locality is 704 m off the Farallon Islands in central California, whose southernmost record is off San Clemente Island, and whose known bathymetric range is 412-704 m. Whether or not these specimens are conspecific with *S. stearnsii* is under investigation and will require comparison to the somewhat smaller (2.5 cm length) holotype of Dall's species. A second, deeper, species is undescribed and is represented by several large specimens, two of which exceed 5 cm in length, substantially larger than the typical 1-2 cm maximum adult length for congeners. One specimen is

from the Patton Escarpment (ca. 32.3°N 120.1°W; 1,845m) and three specimens are from Little Joe Seamount (ca. 31.9°N 120.0°W; 2,397 or 2,612 m). Although the three seamounts are along a line less than 300 km long, and both species are alike in their unusually large body size, preliminary phylogenetic analysis based on mitochondrial 16S rDNA reveals that they are not sister species. With five of 17 worldwide (mostly deep water) species of *Stenosemus* included in a phylogenetic analysis, *S. cf. stearnsii* is basal and the undescribed species groups in a derived position within the *Stenosemus* clade. Their diet and longevity are unknown so it remains an open question how they are able to get so large living on seamounts at bathyal depths.

RIBS OR NO RIBS: GIRDLE SCALES AND THE PHYLOGENETIC AFFINITIES OF TWO CHITONS FROM THE OGASAWARA ISLANDS (JAPAN)

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Two chitons from the Ogasawara (or Bonin) Islands, about 1,000 km south of Tokyo, Japan, have distinctive morphological and 16S ribosomal DNA differences from each other and from known species. Their inclusion in a preliminary 16S phylogenetic analysis supports their close association with *Ischnochiton (Haploplax) comptus* (Gould, 1859), which is common near Tokyo. This association was partly surprising because only one of two Ogasawara chitons resembled *I. (H.) comptus* in bearing relatively large and smooth girdle scales, whereas the other specimen was more like another species that is common near Tokyo, *Ischnochiton (Ischnochiton) boninensis* Bergenhayn (1933), in having much smaller girdle scales that were conspicuously ribbed. The surprise is that the Ogasawara chiton that has ribbed girdle scale like *I. (I.) boninensis* clearly groups more closely to *I. (H.) comptus*, based on 16S comparisons. This association of the two Ogasawara specimens and *I. (H.) comptus* has high bootstrap support, indicating that our phylogenetic results are robust and implying that ribs on girdle scales are likely a rather labile trait. This leads us to challenge the notion that ribs on girdle scales have much systematic value. In particular, the lack of ribs on girdle scales have been emphasized in the diagnosis for the subgenus *Haploplax* Pilsbry (1894) and our results indicate that this is likely an artificial grouping. Our study could lead to a comparative phylogenetic framework for testing the adaptive value, if any, for having or lacking ribs on girdle scales.

***Ariolimax* AND *Haplotrema* AS DEPICTED BY TLINGIT ARTISTS**

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Ariolimax and *Haplotrema* are common land snails in the lands of the Tlingit people, southeast Alaska. Recently four Tlingit artists, three at my request, created Tlingit renderings of the snails. The silversmith engraved *Ariolimax* on both a silver bracelet and a gold bracelet; the two

weavers incorporated *Haplotrema* and *Ariolimax* in weavings; and the carver created a wooden *Ariolimax* ceremonial mask.

THE FISHERY OF THE MANGROVE BLACK ARK *Anadara tuberculosa* (SOWERBY) (BIVALVIA: ARCIDAE) IN BAJA CALIFORNIA SUR, MÉXICO

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The Arcid bivalve mollusk *Anadara tuberculosa* (Sowerby, 1833) is an important commercial and subsistence resource in many estuaries along the Pacific Coast from México to Peru. Average landings over the last 15 years are 587 tons of fresh whole weight coming from Bahía Magdalena and Laguna San Ignacio, Baja California Sur, México. The mangrove black ark (also called cockle and locally “pata de mula”) lives buried in muddy sediments of mangrove swamps, between tree roots, mainly *Rhizophora mangle* and *Laguncularia racemosa*. This species has high fecundity and good growth rate, reaching commercial size (50 mm shell length in natural conditions) at two years. This work analyzes landings and growth data of *A. tuberculosa* in order to identify trends, catch statistics recorded from 1991 to 2006. Catch data reveal considerable fluctuations along with a trend towards decline. No defined seasonal exploitation pattern was observed, but on average the months with the highest catches coincide with the highest reproductive activity. Evidence was found of a decrease in black ark density, which might be accounted for by the fishery. The parameters derived from the von Bertalanffy growth equation confirm that individuals reach the minimum catch size of 50 mm in a little more than one year. Catch sizes ranged between 40 and 80 mm. The parameters of growth estimated for each stock were: Los Praditos $L_{\infty} = 93.26$ mm, $K = 0.99$ per year and $t_0 = -0.217$, and Santa Elenita: $L_{\infty} = 88.48$ mm, $K = 0.90$ per year and $t_0 = -0.601$. However, small black arks of less than 40 mm were not well represented. The growth index values ($\emptyset' = 0.09$ and -0.06 respectively) indicate changes in growth patterns between zones. It is necessary to consider that the estimation method requires that the population size structure be represented in base samples, but no specimens smaller than 40 mm were found in this study, so K is likely to be overestimated.

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GOOD LOOKIN' SISTERS? COMPETING HYPOTHESES FOR A PAIR OF CHITON SPECIES LIVING TOGETHER NEAR TOKYO, JAPAN

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Attempts to identify a chiton with a striking “zebra” coloration pattern, discovered on an intertidal visit near Tokyo, revealed that two nearly identical appearing nominal species were each reported to have this rare morph, implying that either their common ancestor already had this morph or perhaps they were not distinct species. These species are found under the same rocks and have similar reported geographic distributions in Japan and vicinity. The paradox is that leading authorities have classified these in different genera or subgenera: *Ischnochiton* (*Ischnochiton*) *boninensis* Bergenhayn (1933) and *Ischnochiton* (*Haploplax*) *comptus* (Gould, 1859). If at least one of these alternative subgenera is a natural (i.e., monophyletic) grouping, this would imply that the two species are only distantly related and their similar appearance is most likely convergent. We have confirmed that diagnostic differences in their girdle scales are a consistent basis for separating them: *I. (I.) boninensis* has smaller ribbed scales whereas *I. (H.) comptus* has larger smooth scales. Otherwise, we found no consistent morphological difference. The other 12, mostly Australian, members of *Haploplax* also have smooth girdle scales, which is the sole diagnostic feature for this subgenus. We hypothesized that the Japanese chitons with the rare zebra morph and with or without ribs on their girdle scales could alternatively belong to a single species, closely related but not sister species, or only distantly related but convergent species. We used phylogenetic analysis of mitochondrial 16S ribosomal DNA sequences of 22 total chitons, mostly from Japan and Australia, to test between these alternatives. Our results strongly support reciprocally monophyletic groupings of Japanese vs. Australian species, with no support for a widespread “*Haploplax*” clade. Our evidence implies that the ribs have likely been lost independently in the vicinities of Australia and Japan, and should not be used as the sole basis for grouping worldwide species with smooth girdle scales together as *Haploplax*. Our molecular evidence also confirmed the morphology-based distinction between the two species near Tokyo and further that they are indeed closely related but are not sister species. Instead, *I. (“Haploplax”) comptus* groups closer to two specimens from the Ogasawara Islands, 1,000 km south of Tokyo. Our results also have implications for inferring the tempo and mode of speciation and raise questions about how they now manage to coexist with such a similar habitat and geographic range.

MORPHOLOGICAL DOMAIN AND GENE EXPRESSION PATTERNS IN THE MARINE SNAIL *Lottia gigantea* SOWERBY HIGHLIGHT POTENTIAL INTERACTIONS ALONG THE VENTRAL MIDLINE DURING GASTRULATION

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Our objective is to characterize the morphological domains and gene expression patterns of early development in the newly genome-enabled gastropod mollusk *Lottia gigantea* Sowerby, going from the embryo, through gastrulation, and into the larval adult body plan. Morphological domains are identified using scanning electron microscopy. Patterns of gene expression are characterized by *in situ* hybridization. Genes examined include *L. gigantea* orthologs to signaling pathway components and transcription factors that are known to function in gastrulation or early body plan patterning in other metazoans, including orthologs such as BMP, Brachyury, Engrailed, and Hedgehog, among others. Our results show that a complex suite of morphologically distinct sets of cells form domains along and about the presumptive ventral midline over the course of gastrulation. At the same time, complex patterns of gene expression are similarly focused along and about the midline, with different genes often encompassed by a specific morphological domain, or sets of domains. We integrate these findings to identify the origins and dynamics of different morphogenetic domains during gastrulation and the early establishment of the adult body plan in *L. gigantea*. Our work suggests that a detailed characterization of morphogenetic domains in gastrulation is essential to understanding development in *L. gigantea* and in other spiral-cleaving taxa, and to elucidating the developmental mechanisms that underlie the evolution of animal forms across the metazoan tree.

SYSTEMATICS AND BIODIVERSITY OF *Dermatobranchus* (NUDIBRANCHIA: ARMININA) IN THE TROPICAL INDO-PACIFIC

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The opisthobranch genus *Dermatobranchus* is restricted to the Indo-Pacific tropics and temperate southern Africa. Seventeen species have been described from the past literature and are currently recognized as valid. An additional 21 undescribed species have been found and are currently the subject of a major systematic review. These taxa are specialized predators on a wide variety of octocoral prey. As such, they demonstrate a great deal of variation in radular morphology between taxa. Radular differences between taxa that are externally similar are often profound. This paper examines anatomical variation in the *Dermatobranchus* and discusses its potential utility in understanding phylogenetic relationships within the Arminidae.

A CHECK LIST OF CALIFORNIA TERTIARY MARINE MOLLUSCA SINCE KEEN & BENTSON (1944): CONTINUING THE TRADITION

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Check list of California Tertiary marine Mollusca published in 1944 by A. Myra Keen and Herdis Benton is a listing of more than 1,700 Tertiary mollusk species and subspecies described and/or figured from California. The earliest entry of a California fossil mollusk was that of Conrad (1853) who described *Gnathodon lecontei* (= *Rangia lecontei*), a brackish water bivalve purportedly from Carisco Creek (= Carrizo Creek), Imperial County, California, erroneously listed from the Imperial Formation. Species described and/or figured since the Keen and Benton (1944) 1941 cut-off date are listed in this companion volume. In order to record and document these specimens, multiple visits have been made to examine the type collections at the California Academy of Sciences (San Francisco), the National Museum of Natural History (Washington D.C.), the San Diego Natural History Museum, the University of California Museum of Paleontology (Berkeley), and the University of California, Riverside, as well as that in the Natural History Museum of Los Angeles County in Los Angeles. To date more than 4,500 entries of species and subspecies described and/or figured since 1941 have been documented in 325 references and more than 150 formations and/or members throughout California. Data included with each entry (when known) include original generic assignment, reference, publication, age, formation, specific locality, locality number, type number, and remarks, which may include taxonomic changes and specimen disposition.

ECOLOGICAL DYNAMICS IN A CHANGING ENVIRONMENT: RESISTANCE OF MARINE PALEOCOMMUNITIES TO PRIMARY PRODUCTIVITY DISRUPTION IN THE LATE MIOCENE CARIBBEAN

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The Neogene uplift of the Central American Isthmus was coincident with a significant regional marine extinction in the Caribbean. Our study focuses on stratigraphically adjacent marine mollusk communities from the upper Miocene of the Dominican Republic. Paleocommunity structure and dynamics are characterized in order to understand ecological changes in the time period leading up to the final separation of the Caribbean and Pacific Oceans. All shells complete enough to be identified to species are counted in each sample. Relative abundance and trophic properties are used to describe each sample, allowing the construction of meta-networks

representing trophic relationships. To build the networks, species within each community are parameterized ecologically and partitioned into guilds, where members of a guild share similar ecological characteristics such as position on substrate, motility and mode of feeding. Links between guilds represent potential trophic interactions of guild members. Trophic networks are reconstructed probabilistically to reflect uncertainty in both community composition and biotic interactions. We then use a trophic network model to simulate disruptions of primary productivity to each community and assess the sensitivity of the networks to disturbance. Initial results show fluctuations in the abundance of many bivalve and gastropod families between samples. Because the extent to which secondary extinctions propagate through a network is a function of both taxonomic and ecological diversity, communities represented by the samples respond differently to perturbations of the same magnitude.

ARCHITECTS OF THE BERKELEY LEGACY OF CENOZOIC MOLLUSCAN PALEONTOLOGY

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Following an initial phase of geological and paleontological reconnaissance along the western margin of North America, molluscan paleontology moved beyond basic taxonomic description and established itself as a major academic discipline at both the University of California, Berkeley, and Stanford University. The Berkeley legacy began to take shape with the formation of the Department of Paleontology and appointment of **John C. Merriam** as its first professor. Students of Merriam who had the greatest impact on the field during this initial academic phase were **Bruce Lawrence Clark**, **Roy Ernest Dickerson**, and **Earl Leroy Packard**. Clark (PhD 1914) remained at Berkeley, succeeding Merriam in 1918. Two years after completing his degree, Clark had already published monographic studies of the molluscan faunas of the San Pablo Group and the San Lorenzo Series (an impressive 376 pages plus 61 plates). Packard (PhD 1916) published his systematic monograph of mactrid bivalves the same year that he completed his degree and went on to become Professor of Paleontology at the University of Oregon. Dickerson (PhD 1914) had published five substantial papers on Eocene molluscan faunas within two years of completing his degree and went on to become Curator of Invertebrate Paleontology at the California Academy of Sciences.

Other students of Merriam completed and published theses in a growing tradition of dissemination via the University of California Publications in Geological Sciences. These included **Walter Atheling English** (1913, the *Agasoma*-like gastropods), **Bruce Martin** (1913, descriptions of new species of California Neogene mollusks), **Jorgen O. Nomland** (1915 – 1917, mollusks of the Jacalitos, Etchegoin and Santa Margarita beds), and **Carroll Marshall Wagner** and **Karl Howard Schilling** (1918, mollusks of the San Lorenzo Group).

Clark not only succeeded Merriam in the Department of Paleontology, but also became the first director of the Museum of Paleontology when it was established in 1921. During the next 30 years, Clark and his students continued and broadened the Merriam tradition of field collection, faunal documentation, systematic description and revision, and creation of a molluscan

biostratigraphic framework for the eastern Pacific margin. Clark's most influential students included **Hubert Gregory Schenck** (PhD 1926), who also acknowledged James Perrin Smith at Stanford as one of his mentors and who subsequently became influential in shaping the molluscan tradition at Stanford; **Harold Ernest Vokes** (PhD 1935), who merged and integrated the study of west coast mollusks with larger global molluscan inquiry during his years with The Johns Hopkins University and Tulane University; and **John Wyatt Durham** (MA 1936, PhD 1941), who succeeded Clark on the Berkeley faculty in 1947. Durham's 1944 monograph designating seven "megafaunal zones" in the Paleogene of western Washington was the first use of the Opeelian assemblage-based concept of zonation in the Pacific coast Tertiary.

Some of Clark's students left basic molluscan paleontological research for careers in the oil industry. Although they did not assume prominent academic positions, they contributed important molluscan faunal and taxonomic monographs, catalogs, and new theoretical insights and ideas about climate change, molluscan provinces and paleobiogeography, speciation, nomenclature and classification, migration and faunal exchange, genetics, variation, and mechanisms of evolution. Students of Clark who made major contributions to molluscan paleontology include **Marcus Albert Hanna** (PhD 1926, *Venericardia*, Eocene mollusks from the La Jolla Quadrangle); **Henry William Corey** (MA 1929, mollusks of the Vaqueros and Miocene of California); **Thomas John Etherington** (PhD 1930, Stratigraphy and fauna of the Astoria Formation); **Nellie May Tegland** (PhD 1931, *Galeodea* and the molluscan fauna of the type Blakeley Formation); **Charles Warren Merriam** (PhD 1934, turritellid gastropods); **Francis Earl Turner** (PhD 1934, Eocene mollusks of western Oregon); **William Lloyd Effinger** (MA 1936, the Gries Ranch molluscan fauna in Washington); **John William Ruth** (MA 1938, *Siphonalia*), and **Herdis Benton** (MA 1938, PhD 1941, *Exilia* and a monumental nomenclatural, systematic, and bibliographic catalog of California Tertiary marine mollusks and literature with Dr. **A. Myra Keen** of Stanford).

During the Clark era there was considerable informal joint mentorship by molluscan paleontologists at major west coast institutions. Durham and Effinger had both begun their studies at the University of Washington under Professor **Charles Edwin Weaver**. Weaver sent them to Berkeley to complete their studies under Clark's supervision. Although Turner received his degree from Berkeley, he acknowledged Earl Packard at Oregon State University, for the primary mentorship of his research on the Eocene mollusks of Oregon. However Turner also received support and encouragement from Clark as well as financial support from UCMP benefactress **Annie Alexander**. Alexander was, in fact, notably generous in her support of molluscan field work by graduate students at other institutions as well as at Berkeley.

Clark's own research and publication during the years of his Berkeley professorship were formidable. He is best known and most often cited for his monographic work on Tertiary bivalves and Pacific Coast Eocene faunas and biostratigraphy. Less well known are his contributions on the nature of species, the mechanisms of speciation, and processes of dispersal and migration underlying the geographic distribution of Tertiary mollusks. He joined the debate amongst geneticists over the role of natural selection and adaptation, arguing from paleontological data in support of Sewall Wright's arguments for the importance of isolation and genetic drift.

By 1947, when Durham moved from a faculty position at Cal Tech to Berkeley, approximately 1,700 species of Tertiary marine mollusks had been described and illustrated from California alone. The UC Museum of Paleontology had become a major repository for molluscan type specimens. Molluscan paleontology was entering an explosive phase of interpretive research and publication that had its primary interfaces with the Earth sciences. Durham had a phenomenal

curiosity and ability to recognize interesting problems. He encouraged the application of new methods and the development of new characters for the revision of difficult taxonomic groups. Students who completed dissertations on important Cenozoic taxa include **Richard Case Allison** (PhD 1967, turritellid gastropods) and **Clifford Melvin Nelson, Jr.** (PhD 1974, *Neptunea*). As opportunities in the petroleum industry declined, fewer students continued the molluscan biostratigraphic tradition, with the notable exception of **Oluwafeyisola Sylvester Adegoke** (PhD 1966, Stratigraphy and Paleontology of the Neogene formations of the Coalinga region).

Durham's most influential student in Cenozoic molluscan paleontology is **Warren Oliver Addicott** (PhD 1956), whose career with the Paleontology and Stratigraphy Branch of the U.S. Geological Survey in Menlo Park set new standards for monographic systematics, faunal and biostratigraphic documentation, and photographic illustration as well as initiating new insights and integration of molluscan research with active margin tectonics, refined climate curves, latitudinal distributions based on marine mollusks, increased radiometric age control on molluscan faunas, extension of molluscan paleontological interpretations into Alaska, and fostering exchange and collaboration with Japanese molluscan paleontologists.

The scope of Cenozoic molluscan paleontology broadened through Durham's mentoring of students in non-marine research, including **Dwight Willard Taylor** (PhD 1957, fresh-water mollusks), **James Ronald Firby** (MA 1963, PhD 1969, fresh-water mollusks), and **Barry Roth** (PhD 1979, who went on from the study of Pleistocene marine mollusks to terrestrial gastropods). Marine molluscan research expanded temporally into the Cretaceous and spatially across the border into Mexico with the studies of **Edwin Chester Allison** (MA 1954, PhD 1964).

Durham's own research turned increasingly away from mollusks to echinoderms and from the Tertiary Period to the Early Cambrian. Students completing theses on the systematics of non-molluscan taxa included **Victor August Zullo** (MA 1960, PhD 1963, barnacles), **Daniel Bryan Blake** (PhD 1966, asteroids), **Edward Carl Wilson** (MA 1960, PhD 1967, Paleozoic corals), **Jack Dale Nations**, (PhD 1969, crabs), **Carol Daily Wagner Allison** (MA 1963, PhD 1970, echinoids), **Roland Anthony Gangloff** (MA 1963, PhD 1975, archaeocyathids) and **Penny A. Morris-Smith** (PhD 1975, bryozoans).

Durham encouraged research on living as well as fossil mollusks. **John James Oberling** (MA 1951, PhD 1955) and **Copeland MacClintock** (PhD 1964) conducted some of the first detailed analyses and characterization of molluscan shell structure. **William Keith Emerson** (PhD 1956) brought the study of fossil and living scaphopods together for the first time and launched a long and productive career in malacology at the American Museum of Natural History.

At the time of his retirement in 1975, Durham had set the stage for a new molluscan research at Berkeley that would further diversify to include actualistic paleoecological studies, identification and designation of recurring Tertiary molluscan communities, constructional morphological analysis of molluscan features, a new method of molluscan paleobathymetric interpretation, studies of the taphonomic information content of the molluscan record, biological interpretations based on the molluscan larval shell, development of new character sets for cladistic analyses of living and fossil mollusks, recognition and interpretation of chemosymbiotic molluscan cold-seep assemblages, inclusion of molecular data in molluscan phylogenetic analyses, reinterpretation of the Eocene-Oligocene mass extinction and greenhouse-icehouse climatic transition, experimental analyses of mollusk-substrate interactions, studies of the changing roles of mollusks in Pacific Coast intertidal communities, and revision of the higher level systematics and phylogenetic relationships of marine mollusks.

The collections of Cenozoic mollusks in the Museum of Paleontology continue to grow, in spite of increasingly severe space constraints. Rescue by the Museum and UC Regents of the Tertiary mollusk collections from the U.S. Geological Survey in Menlo Park carries a significant burden of responsibility as well as marvelous new opportunity. Dissolution of the Paleontology and Stratigraphy Branch and demise of basic research at the Survey has been recognized in the paleontological community as a "scientific disaster of epic proportions." The Berkeley challenge is to expand as well as maintain its unparalleled molluscan paleontological collections and to appoint new faculty and curators who will continue to train students and postdoctoral scholars, foster new collaborations and vision, and expand this remarkable legacy.

SHELLS OF CONTENTION: THE OCHSNER-OLDROYD-DALL CONTROVERSY

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The 1905-1906 Galapagos expedition of the California Academy of Sciences (CAS) spent a year and a day collecting scientific specimens in the volcanic archipelago that would become known as "Darwin's islands." Expedition organizer and then CAS Director Leverett Mills Loomis (1857-1928) was not an adherent of Darwinian evolution. Among the eight field collectors hired by Loomis to serve as sailor-scientists during the 17-month expedition was 25-year-old Washington Henry Ochsner (1879-1927), who was the expedition's geologist, but who was also charged with collecting modern and fossil mollusks. Following the successful completion of the Galapagos expedition in November 1906, and in light of the complete destruction of the California Academy of Sciences in the earthquake of April 18, 1906, and especially in the three days of firestorms that followed, Ochsner began his taxonomic analysis of the fossil marine mollusks and of the land snails of the islands, based on some 25,000 to 30,000 specimens he collected during the expedition. He continued this work, perhaps with an overly ambitious agenda, from 1906 to 1915, consulting and collaborating with James Perrin Smith (1864-1931) at Stanford University. Ochsner had signed a contract with the Academy prior to the expedition, about which he wrote, "Chief of my privileges was the agreement that the results of our hard, dangerous work in collecting be published by the Academy." In 1915, Ida Shepard Oldroyd (1856-1940) came to Stanford as an assistant in the Department of Geology and began working on the Galapagos material housed there. In early 1916, Ochsner entered into an agreement with Oldroyd for her to visit the United States National Museum (USNM) and the Academy of Natural Sciences of Philadelphia (ANSP) in order to make "a final comparison" before publication. At the USNM Oldroyd consulted with William Healey Dall (1845-1927), who Ochsner believed had agreed to "consideration of honorable mention" on the fossil paper and co-authorship on the land shell work. However, Dall wrote to Ochsner in June 1916 that, "If you would like it I shall be glad to associate your name with mine in the title of the papers." By February 1917, CAS Director Barton Warren Evermann (1853-1932) reported to the governing council of the Academy that Ochsner had revealed in an interview "that in giving data to Dr. Dall he [Ochsner] purposely withheld a sufficient portion of the data to make that which was given to Dr. Dall incomplete and erroneous." Resolution of this bitter scientific controversy did not

occur during the lifetimes of either Ochsner or Dall, who died within 15 days of each other in 1927. Ironically, they were united posthumously as co-authors on the fossil and land snail papers that kept them apart ideologically for some 10 years. The 1905-06 Galapagos expedition found its lasting contribution in furthering the Darwinian debate throughout the 20th century and in the salvation of the Academy after the 1906 earthquake. But the delay in publication by the Ochsner-Oldroyd-Dall controversy severely impeded the malacological success of the expedition.

***Cadlina* IS NOT A CHROMODORID: TAXON SAMPLING, NOMENCLATURAL HISTORY, MORPHOLOGICAL CONVERGENCE AND MOLECULAR PHYLOGENY**

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Morphological homoplasy and limited taxon sampling have hampered understanding of phylogenetic relationships among and between dorid nudibranchs (Mollusca: Gastropoda: Opisthobranchia). Researchers have debated the monophyly of the diverse chromodorid nudibranchs for over 100 years. Recent morphological and molecular phylogenetic studies have added to the debate, but have not resolved this issue. I investigate how outgroup choice and taxon sampling may influence tree topology, support and chromodorid monophyly. I then present phylogenies resulting from different taxon sampling schemes using the same molecular data. Taxon sampling has a strong influence on the resulting phylogenies. *Cadlina* cannot be a member of the chromodorid clade without including many other dorids in that clade. The chromodorid nudibranchs without *Cadlina* are monophyletic and sister to the Actinocyclididae. More thorough taxon sampling with more genes, throughout the dorid nudibranchs is needed, but the preponderance of current evidence supports most current family groupings but suggests *Cadlina* is not a chromodorid.

ELLEN J. MOORE, TERTIARY MOLLUSKS, AND THE U. S. GEOLOGICAL SURVEY

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Ellen Louise James was born on February 6, 1925, in Portland, Oregon, one of three children of Thomas William James and Mildred P. James. Her childhood was spent in Portland, where she and her brother and sister attended the local elementary and high schools. Ellen collected her first fossils as a high school student during one of the regular, usually monthly local geologic field trips run by the Geological Society of the Oregon Country, which would meet in downtown

Portland, and then car pool to a designated location. These fossils, and the excitement they ignited in Ellen, were the inspiration that led her into a long and successful career in paleontology.

After high school, her interest in geology and fossils continued as she attended Oregon State College (now OSU), where she received her Bachelor of Arts degree in Geology in 1946. Her paleontology professor was none other than Earl L. Packard, who had led the original field trip in Portland where she had found her first fossils. Following graduation, she worked for the Army Corps of Engineers, as well as at less exciting endeavors before realizing the need to return to graduate school to further advance herself. She received her Master of Science degree from the Department of Geography and Geology at the University of Oregon in 1950 with a thesis titled “A new Miocene marine invertebrate fauna from Coos Bay, Oregon.” Her thesis advisor there was Ewart M. Baldwin.

Following graduation, she took the required civil service exam needed for employment by the U.S. government, and was subsequently offered a position with the U.S. Geological Survey in Washington, D.C., whose offices were then in the U. S. National Museum building. It was there that she had the opportunity to work with Wendell P. Woodring, an unbelievable dream come true for anyone interested in Cenozoic mollusks. This relationship developed into a lasting friendship and fondness for the man that lasted for many years, as evidenced by her memorial to Woodring published in 1992 by the National Academy of Sciences. If nothing else, Woodring was meticulously thorough in his investigations, and this work ethic must have been instilled in Ellen as well, based on the thoroughness of her later monographic studies on Tertiary mollusks.

While in Washington, Ellen had begun further study of the Astoria Formation fossils of her thesis work, which eventually expanded into a major monograph published as USGS Professional Paper 419 in 1963 [1964]. Previously, in trying to decipher the identity of the Oregon Tertiary fossils described by Timothy A. Conrad in the 1800s, she spent two months at the ANSP in Philadelphia and was able to recognize most of Conrad’s type specimens.

Ellen had married a fellow USGS geologist in 1952, but when that relationship ended, she requested a transfer and was assigned to the Paleontology & Stratigraphy Branch in Menlo Park, California, the western headquarters of the Geological Survey, in 1959. Here she met George W. Moore, also a USGS geologist, and they were married on November 30, 1960, in Palo Alto. Neither of their two children (Leslie and Geoffrey) have followed their parents into geology, but have had successful careers of their own. George Moore died in an automobile accident in late 2007.

If Ellen’s first USGS assignment with Wendell Woodring at the USNM can be considered a stroke of good fortune, her transfer to Menlo Park was no less significant. Here, with Warren Addicott, and later Louie Marinovich, and a host of other paleontologists of various taxonomic persuasions, she was part of the most active group of paleontologists on the West Coast in many years. Menlo Park was THE center of Tertiary molluscan research and its reputation extended across the Pacific to Japan and Russia.

Although Ellen’s list of publications numbers less than 40, many of them are significant. Particularly useful, thoroughly documented and/or exquisitely illustrated are her study of Conrad’s type specimens (1962), her monographs on Miocene and Oligocene faunas of the Astoria Formation (1963 [1964]), Pittsburg Bluff Formation (1976), and Lincoln Creek Formation (1984), her biostratigraphic studies on middle Tertiary molluscan zones (1984) and, with Warren Addicott, on the Pillarian and Newportian molluscan stages (1987), and a series of systematic studies (1983–1992) summarizing the fossil record of the “Tertiary Marine Pelecypoda of California and Baja

California,” published as chapters A through E in U. S. Geological Survey Professional Paper 1228, and continued with Chapters F and G, on her internet web site at <http://www.cmutg.com/chintimp/Tertiary.pelecypods.htm>. Ellen’s publications also catered to the amateur fossil collector with profusely and well illustrated identification guides to local fossils of San Diego County, California (1968) and the Oregon coast (1971, 1994, 2000).

Ellen’s career with the USGS lasted for 37 years, from 1950 to 1987, when she and her husband George retired from active service and moved to Corvallis, Oregon. Upon retirement, Ellen assumed Scientist Emeritus status with the USGS, followed by an appointment as Courtesy Research Associate in the Department of Geosciences at Oregon State University. In 2002, the Cordilleran Section of the Geological Society of America included an Invertebrate Paleontology session in her honor, chaired by Elizabeth Nesbitt. Today, the Western Society of Malacologists is proud to honor Ellen with an Honorary Life Membership in the Society in recognition of her lifetime achievements and contributions to the study of Tertiary mollusks of the Pacific Coast region.

Information above was derived from a variety of sources, including my own personal recollections, as well as those of her friends and colleagues, particularly Judy Smith, Carole Hickman, and Liz Nesbitt. A short summary of Ellen’s career is given in the Preface to her book, *Fossil shells from western Oregon – A guide to identification* (2000, pp. viii-ix).

PALEOCLIMATIC INFERENCES FROM LATE PLEISTOCENE (LATE LAST-INTERGLACIAL) MARINE INVERTEBRATE FAUNAS FROM THE BIRD ROCK TERRACE, PACIFIC BEACH AND OCEAN BEACH, SAN DIEGO COUNTY, CALIFORNIA*

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Middle and Late Pleistocene estuarine and marine terrace faunas from coastal San Diego County, southern California can be assigned to several depositional episodes that are correlative with dated interglacial sea level highstands of the last half million years as documented in the marine oxygen isotope ($\delta^{18}\text{O}$) record of the deep sea. Local Late Pleistocene faunas can be assigned to either of two sea level highstands of the last interglacial complex (equivalent to oxygen isotope Stage 5), that of substage 5e (~120,000 yr BP), represented by the uranium-series dated Bay Point Formation and correlative Nestor Terrace, and substage 5a (~80,000 yr BP), represented by the lower, U-series dated, Bird Rock Terrace. Whereas substage 5e faunas are well documented locally, substage 5a faunas were previously recognized only from rocky-shore marine-terrace habitats around La Jolla and along the outer coast of southern Point Loma.

A re-evaluation of previous marine terrace assignments, based in part on newly collected fossil assemblages, suggests that marine invertebrate faunas from the lowest terrace along Pacific Beach, and farther south in Ocean Beach, represent the ~80,000 yr sea level highstand rather than the ~120,000 yr highstand and thus are assignable to the Bird Rock Terrace rather than to the

Nestor Terrace. These terrace reassignments are supported by their geomorphic position as well as by the temperature (*i.e.*, zoogeographic) aspect of their respective faunas.

In Pacific Beach, newly collected faunal assemblages derived from sewer trenching activities on Loring Street yielded a composite fauna of approximately 150 species of marine invertebrates, being represented by 46 bivalves, 80+ gastropods, two scaphopods, five or more chitons, clionid sponge borings, perhaps three bryozoans, five polychaete worms, three or more barnacles, hermit crab shells and crab claws, two urchins and trace fossils. Farther south, another excavation adjacent to Felspar Street yielded a fauna of more than 110 invertebrate species, mainly bivalve and gastropod mollusks. In Ocean Beach, sewer trenching activities in two areas (San Diego City Sewer Group jobs 545 and 719) resulted in several collections, with composite collections of approximately 140 and 124 species. The collections from Pacific Beach and Ocean Beach represent the most diverse faunal assemblages known from these two areas.

Paleoclimatically, the faunas from Loring Street and Sewer Group 545 yielded the most interesting array of species, being represented by seven and three species, respectively, with extralimital northern or northward-ranging modern distributions. Extralimital northern species in these faunas (and their modern southern geographic range endpoints) include the bivalves *Macoma inquinata* (rare south of Santa Barbara, to Mugu Lagoon) and *Entodesma navicula* (rare south of Shell Beach, San Luis Obispo Co.), the turban-shell gastropods *Tegula montereyi* (south to Santa Barbara Island) and *Tegula brunnea* (San Miguel Island and Redondo submarine canyon, but rare south of Point Conception), and the chiton *Cryptochiton stelleri* (San Nicolas Island, but rare south of Monterey). The presence of these cool-water extralimital northern species, in addition to several more northward ranging, cooler-water species, supports their assignment to the ~80,000 year BP cool-water sea level highstand of substage 5a, rather than to the ~120,000 year BP warm-water sea level highstand of substage 5e. The recognition of these extralimital northern species in the San Diego area, and extending at least as far south as Punta Banda in northwestern Baja California, is evidence of the southward migration of typically Oregonian provincial species during the cool, terminal phase of the last interglacial period, when sea level was on the order of six to seven meters below its modern level.

Specimens of the solitary coral *Balanophyllia elegans* from several of the Pacific Beach and Ocean Beach localities, as well as from the type locality of the Bay Point Formation on Crown Point in Mission Bay, are being dated by uranium-series ($^{230}\text{Th}/^{234}\text{U}$) methods, which should confidently establish the ages of their respective assemblages.

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BANANA SLUGS IN THE BAY AREA NATIONAL PARKS: DISTRIBUTION OF *Ariolimax* (STYLOMMATOPHORA: ARIONIDAE) SPECIES

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As part of a study of the phylogeography of the genus *Ariolimax*, we have surveyed the various units of the National Park system in the greater San Francisco Bay area (California) to

determine the presence and identity of *Ariolimax* spp. In general, *Ariolimax* are likely to be present wherever the water table is sufficiently high to provide moist soil during dry periods. Specimens were collected by hand while walking on trails and identified by dissection and/or molecular data (3 mitochondrial and 2 nuclear genes). We have not found any slugs in Pinnacles National Monument (located in Monterey and San Benito Counties), although it is possible that they exist in some of the moist creek canyons. If present, they would most probably be either *Ariolimax* (*Ariolimax*) *buttoni* or belong to a possible new species of the subgenus *Meadarion* (Pilsbry, 1948), which is being described (Pearse, *et al.*, unpublished) from material collected from Fremont Peak, located farther north in the Gabilan Mountains along the Monterey - San Benito County line. *Ariolimax buttoni* has also been collected from Fremont Peak. Slugs were sought but not found in Eugene O'Neill National Historic Site in Contra Costa County but the proximity of the park to the wooded areas of Mount Diablo suggests that *Ariolimax* (*Ariolimax*) *buttoni*, the only species of *Ariolimax* previously identified from the East Bay (Leonard, *et al.*, 2007), could occur in the park. Similarly we did not obtain specimens from John Muir National Historical Site (Contra Costa County) although a park ranger subsequently reported seeing one on Mt. Wanda within the park. This was also likely to have been *A. buttoni*. Specimens collected from parks north of the Golden Gate (Muir Woods National Monument and Point Reyes National Seashore, Marin County) have all been *A. buttoni*.

Ariolimax buttoni, including both phallate and aphallate forms (Leonard, *et al.*, 2007) were also collected from wooded areas of the The Presidio (San Francisco County). Banana slugs have not been collected at Fort Point National Historic Site (San Francisco County) but its proximity to The Presidio suggests that *A. buttoni* will be at least occasionally present. *Ariolimax* (*Meadarion*) *brachyphallus* has not yet been found in The Presidio but it has been described from San Francisco County (Mead, 1943) and should be looked for at The Presidio. The Golden Gate National Recreation area (GGNRA) consists of a variety of widely dispersed units in Marin, San Francisco, and San Mateo Counties. *Ariolimax* (*Meadarion*) *californicus* was collected from the Phleger Estate unit of the GGNRA in San Mateo County. *Ariolimax californicus* is the only species found in that portion of the San Francisco Peninsula so far. The Sweeney Ridge, Milagra Ridge, and Mori Point units of the GGNRA farther north in San Mateo County offer limited habitat for slugs and so far none has been found. These units warrant further study since their location suggests that they may be on or near a species boundary between *A. brachyphallus* and *A. californicus*. Specimens collected from the Alcatraz unit of GGNRA (Alcatraz Island between Marin and San Francisco Counties) have clustered with *A. californicus* on molecular traits but have a novel morphology with a short, blunt epiphallus unlike that of either *A. brachyphallus* or *A. californicus*, although more similar to that of *A. brachyphallus*. This novel morphology has also been seen in a specimen from Buena Vista Park (San Francisco County). So far the molecular data do not provide good separation among the species within the *Meadarion* clade. *Ariolimax californicus* differs in hatchling color from *A. brachyphallus* collected from Monterey and San Luis Obispo Counties. *Ariolimax californicus* has a transparent hatchling whereas *A. brachyphallus* has a dark, almost black, hatchling. We do not yet have data on hatchling color from Alcatraz slugs. This study was supported by NPS grant PWR-PORE R8538060029 through Point Reyes National Seashore to JLL and JSP. The molecular work was supported by funding to TB.

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HISTORY OF THE MUSEUM OF PALEONTOLOGY, UNIVERSITY OF CALIFORNIA, BERKELEY

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Over the last 150 years, the University of California Museum of Paleontology (UCMP) developed a very large collection of all fossils, including marine and non-marine fossil and modern mollusks, providing resources for research, teaching and outreach. UCMP's history and mollusk collections are rooted in the formation of the State of California, and its early decisions about resources and education. John C. Fremont collected the first fossils from California on his expeditions into Mexican California in the 1840s. He accepted the surrender by Andrés Pico in January 1847. That and the discovery of gold in 1848, resulted in the gold rush of 1849 and statehood for California in 1850. The new Legislature needed information on the mineral and natural historical wealth of California. At first J.B. Trask was paid to do the work, but later the Legislature appointed J.D. Whitney as State Geologist and Director of the Geological Survey of California (1860–1874). Some of these early collections formed the foundation of the paleontological museum of the University of California, founded in 1868; others were taken by Whitney to Harvard and by W. M. Gabb to Philadelphia. Many of the modern and fossil mollusks collected by the Survey were identified and new molluscan species described by James G. Cooper.

Joseph Le Conte, the first geologist, natural historian and botanist appointed to the faculty, encouraged paleontology through his lecturing, particularly on evolution and fossils, his students, and his acquisition of fossil collections for the university. His most brilliant student, John C. Merriam, became the first professor of paleontology, and though his interactions with the wealthy Annie Alexander, who supported paleontology at Berkeley, the first Department and later Museum of Paleontology were formed in 1909 and 1921. Although developments were not always smooth, a strong and internationally recognized paleontology program emerged before World War II, followed by increasing strength and diversity of all programs.

Molluscan studies began early. By 1915, the Paleontology Department had a collection totaling over 150,000 invertebrate, 15,000 vertebrate and 3,000 plant fossils, of which several hundred were type specimens. Merriam contributed papers on mollusks, followed by Bruce L. Clark, appointed in 1918 and later as first Director of UCMP in 1921. Later J. Wyatt Durham, Carole S. Hickman and David R. Lindberg took over molluscan and invertebrate responsibilities in the museum. The collections are constantly increasing as students, faculty, staff, other institutions, and others continue to donate mollusks, both fossil and modern. A recent example was the large

and important USGS collections, which contained considerable Alaskan material. Today, fossil mollusks are an important part of UCMP's holdings, which are in addition to the collection of modern species that includes more than half a million specimens.

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SUBSTANTIAL PROGRESS TOWARD THE COMPLETION OF THE GASTROPOD VOLUMES FOR THE NORTHEASTERN PACIFIC

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Two books (illustrated manual/taxonomic revisions) on the long-neglected northeastern Pacific gastropod fauna are underway. The first book treats the gastropod species of British Columbia, Oregon, California, and northern Baja California. With the help of a part-time imaging assistant, there are now over 400 black and white plates with numerous photos that include most type specimens. The text with species accounts has now been merged in two columns below the figures and on facing pages. The format is sufficiently detailed to allow the inclusion of at least 350 new species. The total number of treated species is approximately 1,400. Completion of the text for the southern book is anticipated within a year, for publication by the Santa Barbara Museum of Natural History. The second book treats the gastropod fauna of Alaska and the Bering Sea (including Arctic Alaska), as well as species extending south to 40° N for both the northeastern Pacific and the northwestern Pacific. Inclusion of the northwest Pacific species has been possible due to the 2006 publication of Kantor and Sysoev's illustrated catalog of marine gastropods of Russia. The species of British Columbia, Washington, and Oregon are to be included in both books. The plates for the northern book are 90% finished. It is anticipated that sales generated by the publication of the southern book will finance the subsequent publication of the northern book.

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MORPHOLOGICAL AND BEHAVIORAL ADAPTATIONS FOR CONTROL OF BODY TEMPERATURE DURING AERIAL EMERSION IN NORTHEASTERN PACIFIC *Littorina*: A MECHANISTIC TEST

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Littorine snails are often the highest-living marine organisms in the intertidal zone, and as a result they are exposed to large changes in environmental conditions as tides rise and fall. These snails have been the subject of many studies exploring potential adaptations for life under these extreme conditions, especially with regard to thermal regulation and control of desiccation. I have constructed a biophysical heat-budget model for four species of *Littorina* found on the west coast of North America in order to test long-standing hypotheses about morphological and behavioral traits considered to be beneficial in controlling body temperature during warm periods. Behavioral changes such as modifying contact area with the substratum and re-orienting the shell are shown to keep snail body temperatures 2-4°C cooler than snails not carrying out these behaviors. In contrast, many of the morphological characteristics of shells, such as color and shape, are shown to contribute relatively little to reducing body temperature on hot days, with temperature shifts of less than 1°C between morphs. The small changes in temperature afforded by different shell morphologies may be due in large part to the small size of these species.

THE PHYLOGENY OF *Phyllodesmium* (EHRENBERG 1831): ADAPTATIONS AT THE CENTER OF DIVERSITY

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The facelinid genus *Phyllodesmium* (Ehrenberg, 1831) consists of approximately 27 morphologically diverse species that prey upon soft-bodied corals. At least 11 species have yet to be described, making it an interesting genus for testing phylogenetic hypotheses. One of the most interesting adaptations found in this genus is the widespread participation in a symbiotic relationship with photosynthetic dinoflagellates in the genus *Symbiodinium*. Many species in *Phyllodesmium* are able to retain zooxanthellae, which they obtain from their alcyonarian food source. A large degree of anatomical adaptations that enhance the ability to retain zooxanthellae make this group ideal to study the progression of symbiosis as it evolved in these animals. Histological studies have shown a positive relationship between the extent of digestive gland branching and the zooxanthellae retention abilities of these nudibranchs. Based on this observation, it is thought that animals with minimal or no branching are more primitive species, whereas animals with vastly branched digestive tissue are highly evolved for maintaining algal symbionts. In this study, five new species of *Phyllodesmium* from the Philippine Islands and Japan are described. A preliminary examination of the *Phyllodesmium* phylogeny suggests that species with

digestive gland branching and zooxanthellae are more derived, however molecular data could add confidence to this.

THE HISTORY OF PALEONTOLOGY IN THE SOUTHERN SANTA CRUZ MOUNTAINS, CALIFORNIA

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The southern Santa Cruz Mountains of central California expose over 7,000 meters of marine Cenozoic strata. All of the epochs are represented, many by richly fossiliferous sedimentary formations. Lay descriptions of fossils from this area date back to the 1850s and 1860s. Scientific interpretation of the region's geology and fossils was later facilitated by Charles Lewis Anderson, a physician and naturalist who lived in Santa Cruz from 1867 to 1910. He served as mentor to young naturalists in the area, including Laura Hecox. A collector and museum founder, Miss Hecox assisted many scientists, including paleontologist Ralph Arnold of Stanford University. Early 20th century naturalists John Strohbeen and Harry and Mary Turver helped procure fossils for U.C. Berkeley and the California Academy of Sciences. In the early to middle 1900s the region benefited from studies by students at Stanford University. The results included the *Description of the Santa Cruz Quadrangle, California* by J. C. Branner, J. F. Newsom, and Ralph Arnold (1909), and later by refined studies within that quadrangle by Earl E. Brabb, Roscoe M. Touring, and Joseph C. Clark, among others.

THE MARINE MOLLUSKS AND DEPOSITIONAL HISTORY OF THE MIOCENE TO PLIOCENE PURISIMA FORMATION, NORTHERN MONTEREY BAY, CALIFORNIA

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The cliffs along the northern shore of Monterey Bay expose approximately 325 m of upper Miocene and Pliocene marine sediments of the Purisima Formation. The formation records an overall shallowing of marine conditions through time, based on evidence from geology, invertebrate fossils, vertebrate fossils, and trace fossils. Nearly a hundred invertebrate taxa have been recorded, mostly mollusks. The mollusks occur as isolated specimens and in beds ranging from a few centimeters to over a meter in thickness. Beds vary widely in faunal composition and quality of preservation. Exceptional preservation of mollusks in some beds reveals anatomical details not usually visible in specimens from other localities in California.

IS SELF-FERTILIZATION POSSIBLE IN NUDIBRANCHS?

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Nudibranchs (Gastropoda: Opisthobranchia) are internally fertilized simultaneous hermaphrodites with a complex reproductive system. Even though their reproductive systems vary greatly in organization, adults normally copulate reciprocally with the gonopores aligned so that the penis of one animal can deposit free sperm in the vagina of the other (Hadfield & Switzer-Dunlap, 1984). Studies about “sperm-trading” in simultaneous hermaphrodites, as well as about hermaphrodite mating conflicts in outcrossing opisthobranch species (Michiels, 1998; Anthes & Michiels, 2005; Anthes, Putz & Michiels, 2006) are rapidly increasing. However, less work has been done with regard to self-fertilizing hermaphrodites. This report focuses on observations of the reproductive system of several nudibranch gastropods of the genus *Nembrotha* Bergh (1877), where the penis of each specimen was found located inside its own vagina. The review of the literature shows no previous records of penises introduced into the own vagina from any other opisthobranch. We also observed that the penis of all *Nembrotha* species is very long, usually about 3 mm long in those specimens in which the penis is completely extended. The length of the penises in *Nembrotha* species is much longer than those of *Roboastra* and *Tambja* (500 µm – 1 mm; unpublished data), which would permit certain plasticity. In order to obtain solid evidence of self-fertilization in nudibranchs, experiments using adults isolated, as veliger larvae are essential. However, while nudibranch life cycle studies remain scarce and further studies are done, it is important to present here evidence for at least the physical possibility of self-fertilization in this group. The length of the penis of these species could help to sustain such behavior.

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***Architectonica* (GASTROPODA) AND ASSOCIATED WARM-WATER MOLLUSKS USED TO CORRELATE AND DATE SCATTERED OUTCROPS IN THE PLIOCENE OF SOUTHERN AND CENTRAL CALIFORNIA**

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Living representatives of the tropical gastropod genus *Architectonica* in the eastern Pacific are not currently found north of Bahia Magdalena, Baja California Sur, México. Therefore, it is unusual to find them in the fossil record of southern California. We report here on the presence of specimens of *Architectonica*, compared with *A. (Discotectonica) placentalis* (Hinds), as well as associated warm-water molluscan faunas, from 1) the San Diego Formation at the border locality in southwest San Diego County; 2) unnamed Pliocene deposits in the Whittier Hills of Orange County; 3) the so-called “Santa Barbara Formation” at Rincon Point near the Ventura - Santa Barbara County line, and 4) in the Cebada fine-grained member of the Carega Sandstone in the Santa Maria District of northern Santa Barbara County. The presence of other southern extralimital species such as the gastropods *Crucibulum cyclopium* Berry, *Turritella gonostoma hemphilli* Merriam of Woodring and Bramlette, and several larger species of *Conus* at one or more of these localities also supports the existence of warm, subtropical to tropical conditions in southern California in the recent geologic past.

Fossil collections from the San Diego Formation, unnamed strata in the Whittier Hills, and the Carega Sandstone have all been assigned to the Pliocene, whereas those from the so-called “Santa Barbara Formation” have previously been assigned to the Pleistocene based on regional lithologic correlations with the middle Pleistocene Santa Barbara Formation in Santa Barbara County. Extinct mollusks from the Rincon Point exposures of the “Santa Barbara Formation” indicate a Pliocene to early Pleistocene age for the fauna. The associated warm-water fauna further differentiates it from that of the Santa Barbara Formation, which consists of dominantly temperate water mollusks. Therefore, all of these faunas are of potential late Pliocene age.

Microfossil data (planktic foraminifers and pollen), and other proxy data well correlated to oxygen isotope records as well as to the paleomagnetic and cyclostratigraphy records, document a warming event that took place during the Pliocene epoch between 3.3 and 3.15 Ma [= the “mid”-Pliocene warm event (Gauss chron)]. An age determination from planktonic foraminifers from the San Diego Formation border locality overlap this age range (M. Vendrasco, email, 1/2008). We suggest that these warm-water mollusks and associated faunas were deposited during the “mid”-Pliocene warm event, and that specific southern extralimital warm-water mollusks, particularly *Architectonica*, can be used to correlate different formations/outcrops of this age in central and southern California; similar to what has already been done for the middle to late Pleistocene in southern California (WSM Annual Report 32:23-36).

COMPARATIVE PHYLOGEOGRAPHY, HYBRIDIZATION, AND MITOCHONDRIAL CAPTURE IN TWO SPECIES OF CARIBBEAN SEA SLUGS WITH NON-PLANKTONIC DEVELOPMENT

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Mitochondrial DNA is often used in phylogeographic studies and for DNA bar-coding, because it is fast evolving. However, historical or ongoing hybridization can move mtDNA between species (introgression), invalidating conclusions based on common markers like cytochrome oxidase I (COI). Comparative studies of nuclear and cytoplasmic genes from closely related taxa can determine which are valid markers for population-level studies and species identification. *Elysia pratensis* Ortea & Espinosa and *E. subornata* Verrill, sister species of Caribbean sea slugs, lack a dispersing larval stage; thus, populations from different sites were predicted to be genetically divergent. Portions of COI and the nuclear large ribosomal subunit (28S) gene were sequenced from specimens from Florida, five Bahamas islands, Bermuda and Jamaica. Bayesian analysis of COI haplotypes revealed four distinct clades up to 8% divergent in *E. pratensis*, with most sites exhibiting reciprocal monophyly, and Analysis of Molecular Variance revealed highly differentiated populations ($F_{st}=0.935$). However, two *E. pratensis* clades from the northern Bahamas were more closely related to *E. subornata* than to conspecifics, suggesting historical introgression of the mitochondrial genome from *E. subornata* into *E. pratensis*. A fixed difference in the nuclear 28S gene, morphology and host use distinguished the two species. Less population structure ($F_{st}=0.389$) and no phylogeographic breaks were evident in *E. subornata*, which may raft between sites on its host alga *Caulerpa racemosa*. Phylogenetic analyses suggest a history of recurring hybridization and introgression events in the northern Bahamas, where populations of the two species may have been repeatedly isolated together in shallow basins due to Pleistocene sea level fluctuations. Introduction of *E. subornata* into the Mediterranean has been suggested for biological control of invasive *Caulerpa* spp., but its potential for dispersal and hybridization with native species urges a cautious approach.

LIPID DETERMINATION IN THREE SPECIES OF MOLLUSCS: THE GASTROPOD *Strombus gigas* LINNAEUS AND THE CEPHALOPODS *Octopus maya* VOSS AND SOLIS, AND *Loligo pealeii* LESUEUR

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The considerable interest in mollusks is due in part to their importance as food, which has resulted in significant data on various biochemical characteristics of this phylum. Knowing their biochemistry can be of considerable use in understanding their ecology and physiology, and their

characterization and classification within a Chemotaxonomy.

For biochemical characterization, the body of a mollusk should be divided into various body components. These parts can be easily separated from each other by dissection, and yield large enough pieces for chemical analysis. The biochemical composition of these body parts is based on the different amounts of proteins, lipids and carbohydrates present.

The development of tourism and the high demands for sea food in the Yucatán Peninsula have contributed to the exploitation of mollusks such as the octopuses *Octopus maya* Voss and Solis, *O. vulgaris* Cuvier, the squid *Loligo pealeii* Lesueur, and the marine snail *Strombus gigas* Linnaeus. A proper fisheries management program for these resources requires a sustainable collection that benefits both the resources and the human community.

Due to these requirements, it is necessary to generate key biological information about these organisms, which go beyond traditional taxonomy. Therefore, making use of a chemotaxonomy by determining the total quantity of the various classes of lipids (e.g., glucolipids and phospholipids) plays an important role in the characterization and identification of the organisms that have been used and processed. These determinations have special relevance when the entire body of the organism is not available, and one cannot identify them by classic taxonomic methods.

We used Privett's method of column chromatography to extract total lipid content and to determine the lipid classes present in the proboscis, mantle and muscle of three species: *Strombus gigas*, *Octopus maya* and *Loligo pealii*. Our results allowed us to characterize each mollusc by the lipid class percentages of the separate organs. The percentages of phospholipids in the proboscis gave a clear differentiation and separation between the 3 species. The values were: snail, 82.27%; octopus, 63.48%; and squid, 48.51%. Our lipid study results permit a chemotaxonomic identification of these 3 species, and form the basis for future scientific studies to develop a sustainable and responsible fishery plan for these 3 resources.

DETERMINACIÓN DE LÍPIDOS EN TRES ESPECIES DE MOLUSCOS: CARACOL *Strombus gigas* LINNAEUS, PULPO *Octopus maya* VOSS AND SOLIS, Y CALAMAR *Loligo pealeii* LESUEUR

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El interés considerable por los moluscos, es debido en parte a su importancia como alimento, lo que ha resultado en muchos datos sobre una variedad de características bioquímicas de su Phylum. Tales datos bioquímicos podrían ser también de uso considerable en el entendimiento de la ecología, de la fisiología de los moluscos y de su caracterización y clasificación por medio de la Quimiotaxonomía.

Para el propósito de la caracterización bioquímica, el cuerpo de un molusco, por lo tanto, debe ser dividido en varios componentes corporales. Esas son partes, las cuales pueden ser convenientemente separadas las unas de las otras por disección y deben ser de tamaño suficiente para permitir un análisis bioquímico.

Para caracterizar bioquímicamente cada uno de los componentes del cuerpo de un molusco es necesario determinar la cantidad el tipo de cada uno de los constituyentes como son: proteínas, lípidos y carbohidratos.

El desarrollo del turismo y la alta demanda de alimentos del mar en la Península de Yucatán han contribuido a la explotación de moluscos como: el pulpo *Octopus maya* Voss y Solis, y *Octopus vulgaris* Cuvier, el caracol marino *Strombus gigas* Linné y el calamar *Loligo pealeii* Lesueur. Un buen manejo pesquero de estos recursos, se requiere para tener una pesca sustentable y responsable en beneficio de los mismos recursos y de la sociedad en general.

Debido a este requerimiento es necesario generar información científica apropiada aunada a la clasificación taxonómica tradicional. Por lo que, haciendo uso de la Quimiotaxonomía, la determinación de la cantidad de lípidos totales y sus clases (neutros, glucolípidos y fosfolípidos) juega un papel importante en la caracterización e identificación de organismos que han sido manipulados y procesados y estas determinaciones toman relevancia cuando no se tiene el cuerpo entero de estos organismos y por lo consiguiente no pueden ser identificados por la taxonomía clásica.

La metodología que se utilizó para la extracción de los lípidos totales y para la determinación de las clases de lípidos se usó la cromatografía en columna con el método de Privett. La extracción de los lípidos totales y la separación de las clases de lípidos se determinó en tres órganos: (probosis, manto y músculo) en cada una de las tres especies mencionadas.

Los resultados obtenidos en cuanto al porcentaje de lípidos totales y el porcentaje de clases de lípidos permitieron caracterizar cada tipo de moluscos de acuerdo a sus órganos. El órgano probosis en cuanto a los porcentajes de fosfolípidos, fue el que permitió la diferenciación y la separación entre las tres especies estudiadas con los siguientes valores: caracol 82.27%, pulpo 63.48% y calamar 48.51%. Los resultados de este trabajo haciendo uso de los lípidos ha permitido hacer una identificación de estas tres especies estudiadas por medio de la Quimiotaxonomía y sienta las bases para estudios posteriores para que contribuyan de una manera científica a un mejor conocimiento de los tres recursos en cuanto a su manejo pesquero de una manera sustentable y responsable.

REPRODUCTIVE CYCLE OF THE SQUALID CALLISTA *Megapitaria squalida* (SOWERBY, 1835) (BIVALVIA: VENERIDAE) FROM BAHÍA MAGDALENA, BAJA CALIFORNIA SUR, MÉXICO

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Megapitaria squalida (Sowerby) is one of the most abundant bivalves in the northwest of México, but is considered as a species with low commercial value. *Megapitaria squalida* is captured year long without restrictions and recently, in this Mexican region, its catch has been increased. Then, its abundance decreased considerably. To establish an adequate management of the resource, it is essential to know the reproductive cycle of the species. Monthly, from February 2007 to January 2008, 30 specimens of *M. squalida* were collected in Bahía Magdalena, Baja California Sur Their reproductive activity was histologically analyzed and four stages of gonadic development (development, ripe, spawning and spent) were qualitatively established. Also, a quantitative analysis was done using the oocyte mean diameter. The water temperature and the

concentration of chlorophyll *a* (as a measurement of food availability) were registered at the time of collection. A total of 372 clams were obtained with a size of 36 to 110 mm of length ($\bar{X} = 88.25$, $s^2 = 12.18$); 192 females (51.6 %) and 106 males (28.5 %). The total sex ratio was 1.8H:1M ($\bar{X}^2 = 24.8$, $P < 0.05$). Even though this species has been considered gonochorical, the histological evidence revealed the presence of 74 hermaphrodite clams (19.9%). The histological analysis also demonstrated that there were not the undifferentiated, and the ovary spent stages. *Megapitaria squalida* has continuous reproduction, evidenced by the presence of spawning clams (in variable proportion) throughout the study period. However, the mean oocyte diameter was significantly higher in August and December ($P < 0.05$), revealing two important periods of reproductive activity in these months. Even though the oocyte diameter was not significantly correlated ($P > 0.05$) with the temperature or the concentration of chlorophyll *a*, it is evident that the temperature regimen and the high productivity in Bahía Magdalena promote continuous gamete production in the area. In contrast with the well established reproductive seasonality of *M. squalida* in other locality (Ojo de Liebre Lagoon) in Mexico.

ALMOST BY ACCIDENT: THE HISTORY OF NONMARINE MOLLUSCAN PALEONTOLOGY IN THE WEST

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Much of the history of nonmarine molluscan paleontology in western North America came about almost accidentally: specimens collected by paleontologists whose main interest was in other animal groups such as dinosaurs or mammals, or specimens found in marine sections and not recognized as nonmarine until examined by specialists. A recent example of this kind of “indirect” approach is the finding of nonmarine snail fossils in the fossilized dung of Cretaceous duckbilled dinosaurs by Dr. Karen Chin of the University of Colorado. Only in the latter half of the twentieth century have there been paleontologists in the region whose concentration is on land or freshwater mollusks.

BIODIVERSITY OF MOLLUSKS ASSOCIATED WITH THE NONTROPICAL CARBONATE SHELF IN THE GULF OF CALIFORNIA

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This determines the ecological and oceanographic process that affects the communities of mollusks associated with carbonate sediments in the western coast of the Gulf of California. Four data sites were selected: Cabo Pulmo (23° N), Isla San José (25° N), Punta Chivato (27° N) and

Bahía de los Angeles (29° N), where 64 sediment samples were collected along with environmental indicators such as temperature, depth, chlorophyll *a*, transparency, salinity and grain type of the sediment. Abundance and diversity were used as an ecological descriptor of the malacológico benthic community and growth of the species of greater relative value as indicators of calcium carbonate production incorporated to sediments.

The communities of mollusks in the four sites are different in their specific composition in similar environments (shallow water between 2 to 30 m on sandy bottoms). The group exhibits variability in the index of taphonomic condition within the four sites of study, dominating shells of mollusks in good preservation. The maximum value of the diversity index of Shannon-Wiener was obtained in Punta Chivato, with 3.8 bits/indiv. and Cabo Pulmo had the smaller registered values (1.1 and 12 bits/indiv.). Greater specific richness and relative biomass of macromollusks were found in the northern and central zones that displayed eutrophic and mesotrophic conditions in geologic terms and smaller biomass and richness in the south, where greater richness is represented by micro-mollusks in oligo-mesotrophic environment. In Punta Chivato and Isla San José, the highest values of diversity were found and displayed similarity in their mesotrophics conditions. The mollusks, through growth of their shells, deposit to sediments CaCO₃ after dying in proportion to their density; it was considered that individuals of one cohort of *Megapitaria squalida* (Sowerby) at their highest size contributes with 10 g / year of CaCO₃ to sediments, whereas *Chione californiensis* (Broderip), 5 g at year.

THE GASTROPOD GENUS *Bruclarkia* IN TERTIARY STRATA OF THE EASTERN PACIFIC

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The extinct neogastropod genus *Bruclarkia* Trask in Stewart (1927) comprises thirteen species, all of which are endemic to the Paleogene and Neogene of California, Oregon, Washington, Vancouver Island, and Alaska. Shells are fusiform in shape with an inflated body whorl and varying degrees of prominence in spiral ribs and threads. Spire ornamentation is variable as is its morphology, which ranges from smooth with an adpressed suture to stepped with a deeply impressed suture. The aperture is leaf-shaped and the siphonal canal is slightly recurved, though often missing from fossil specimens. Species are distinguished by spire shape, shoulder on the body whorl, and the number and spacing of spiral cords.

The genus first appears as *Bruclarkia vokesi* Hickman (1969), in the Oregon Keasey Formation of the Eocene, and is last seen in the Oregon Astoria Formation of the middle Miocene as *Bruclarkia oregonensis* (Conrad, 1848). A radiation of *Bruclarkia* species occurred in the early Oligocene after a local extinction near the Eocene/Oligocene boundary in the Pacific Northwest wiped out more than ninety percent of mollusk species. The *Bruclarkia* species of the post-extinction recovery fauna were adapted to cool water and their longevity ranged from 3 to 15 million years. They went extinct (enigmatically) about 20 million years later, with no *Bruclarkia* species giving rise to any extant neogastropod.

In a morphological analysis of this genus, more than two hundred *Bruclarkia* specimens (including holotypes) from California, Oregon, Washington, and Vancouver Island, Canada were examined. Fossils were provided by the University of California, Museum of Paleontology (UCMP), California Academy of Sciences, Burke Museum of Natural History, and the author. Poor preservation inhibited analysis of many specimens, especially for siphonal canal and apertural characters, but spire characteristics were generally well preserved and were detailed enough to designate between species consistently. Specimens were grouped into six categories and seventeen character states of shell morphology. By polarizing morphological characters and correlating species with stratigraphic data, a suite of derived *Bruclarkia* shell characters was identified. They include a noded subsutural collar, extensive parietal lip, convex shoulder, a globose, stepped spire, and evenly spaced nodes bordering the sutural collar. To further elucidate the evolutionary history of this genus, further studies should examine; (1) the original and steinkern-preserved protoconchs of *Bruclarkia* to infer larval developmental mode, and (2) shell morphology associations with substrate and inferred depth.

Bruce Clark, the namesake of this genus, was a Professor and Invertebrate Curator of UC Berkeley's Museum of Paleontology (UCMP) during the 1920s. His student, J. Wyatt Durham, also became a professor and curator of invertebrate collections at Berkeley and named three *Bruclarkia* species from the Oligocene of Washington in the 1940s. In 1969, Carole Hickman, an Integrative Biology professor and UCMP curator, described and named *Bruclarkia vokesi* from formations in Washington and Oregon. In 1970, Warren O. Addicott published on the Miocene gastropods and stratigraphy of the Kern River area formations of California, including *B. oregonensis* and *B. yaquinana* (Anderson and Martin, 1914). Two of the most important works on *Bruclarkia* are Ellen J. Moore's treatment of the genus and of the species *B. oregonensis* (Conrad, 1848) and *B. columbiana* (Anderson and Martin, 1914) in careful and detailed monographs of the Oregon Miocene Astoria Formation in 1963 [1964] and the Oligocene Pittsburg Bluff Formation in 1976, respectively.

A DIVERSE CHITON FAUNA FROM THE LATE PLIOCENE (~3 MA) PART OF THE SAN DIEGO FORMATION

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A chiton assemblage consisting of more than 15,000 valves (shell plates) from about fourteen extant and four new extinct species was recovered by George P. Kanakoff (1897-1973) from the richly fossiliferous upper Pliocene part of the San Diego Formation. This is the largest and most diverse fossil chiton assemblage known from western North America, and hundreds of chiton valves are exceptionally well preserved.

The chiton assemblage is dominated by *Callistochiton*, but also includes *Lepidozona*, *Leptochiton*, *Amicula*, *Placiphorella*, *Stenoplax*, *Tonicella*, *Oldroydia*, *Lepidochitona*, and *Mopalia*. These fossils expand the known stratigraphic and paleogeographic ranges of many chiton

genera and species, and provide much needed detail about the Cenozoic evolution of chitons along the West Coast of North America. For example, the occurrence of *Amicula* in the San Diego Formation suggests that this genus had a broader geographic range in the past. The massive number of chiton valves in this deposit allows robust analyses of the ratios of head to intermediate to tail valves. The ratios differ dramatically from the expected 1:6:1, a result that is consistent with counts of chiton valves in modern sediments.

Paleoenvironmental data from chitons, clams, snails, benthic and planktonic foraminifers, ostracods, and other fossils in these particular beds are somewhat conflicting, probably due in part to time-averaging, but the weight of evidence suggests: (1) an inner-neritic (~20 to 50 m depth) continental shelf environment dominated by sandy bottoms, but with patches of rocky substrate; and (2) an annual temperature range about the same as, or slightly colder than, that present along the current San Diego coast. Foraminiferans and mollusks suggest an age of late Pliocene (~3 Ma) for these sedimentary beds.

THE TERTIARY MAY BE TOAST, BUT LYELL LIKED HIS EOCENE OYSTERS FROM GEORGIA

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Charles Lyell spent a good part of his life trying to define the components of the Tertiary, a holdover from Arduino's (1759) division of rocks on the Earth's surface; but now, the Paleogene trumps Tertiary as the term of choice for the triad epochs, the Paleocene, Eocene and Oligocene (Gradstein, *et al.*, 2004). Long before Ellen Moore revealed some of the rich "Tertiary" history of fossil mollusks in the United States, Lyell traveled to the east coast of North America to examine gigantic fossil oysters, *Crassostrea gigantissima* (Finch), from the Eocene of Georgia. The Tertiary may be toast, but the gigantic oysters that Lyell studied in the Paleogene of Georgia may have whetted his Uniformitarian appetite.

Oysters, after all, fit the extreme uniformitarian concept that Lyell espoused: The oysters had a recognizable form throughout their geologic history despite major extinction events. But did they? These oysters were giants, and appeared to share an ecological community much different than those Lyell would have encountered on a modern coastal foray. A paleoecological and taphonomic analysis of the Eocene oysters indicate that they were subtidal, not intertidal in distribution, and flourished in warm, tropical waters with possibly high nutrient loads as indicated by their shell-encrusting and bioeroding fauna; this is a different ecological assemblage than Lyell would have seen on the coast of Georgia.

Gradstein, F. M., Ogg, J. O., Smith, A. G., *et al.* 2004. A geologic time scale 2004. Cambridge University Press, Cambridge, UK. 589 p. (See also: http://www.geotimes.org/nov03/NN_tertiary.html and linked sites).

SUBMITTED PAPERS

alphabetical by first author

HOW AN INDEX FOSSIL LED TO POOR CONCLUSIONS ABOUT STRATIGRAPHY AND STRUCTURE IN NORTHERN CALIFORNIA

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Abstract

Discovery of a thin sandstone bed with the late Paleocene index fossil *Turritella infragranulata pachecoensis* near Fairfield, California, led to the assumption that this bed is part of a simple eastward-dipping homocline that extends dozens of miles to the north. Excavation of the grass-covered hills surrounding the sandstone uncovered a nearly continuous section of sandstone and shale nearly 2,500 feet thick with the Paleocene index fossil in the middle. Abundant foraminifers in shale above and below the sandstone with the index fossil led to the mistaken belief that this section may be the “Rosetta stone” for Paleocene rocks in California where the Paleocene is typically thin, sandy, and sparsely fossiliferous. Coccoliths, Foraminifera, and Radiolaria established that the rocks are extensively faulted and partly overturned, and have Eocene and Late Cretaceous rocks inter-layered structurally with the Paleocene rocks.

Introduction

Discovery of a 3-foot thick sandstone bed with abundant Turritellid gastropods of late Paleocene age (Figure 1) about 4 miles northeast of Fairfield, California and on the southwest flank of Cement Hill, Solano County (Figure 2, area 1), 36°17'30" north latitude and 122°01' west longitude, provides an opportunity to reevaluate the relationships of lower Tertiary formations in this part of California. Cement Hill is named for travertine deposits in and on top of sandstone of Late Cretaceous age (Hart, 1978). In this report, the current study area where the Paleocene fossils were recently discovered is referred to as lower Cement Hill and is located in section 7 of the U.S. Geological Survey Fairfield North 7.5' minute quadrangle, Township 5 North, Range 1 West. Lower Cement Hill is about 23 miles north of the so-called Martinez “formation” or stage area (Weaver and others, 1944) of late Paleocene age near Martinez (Figure 2, area 2). The Martinez “formation” and stage have played a significant role in the development of early Tertiary

stratigraphy in this part of California. The discovery of correlative rocks at Cement Hill was unsuspected and may be helpful in defining the extent of this so-called formation or stage.

Coccolith identification and correlations are by David Bukry, foraminifer identifications and correlations by Alvin Almgren and Kristin McDougall, gastropod identification and correlation by LouElla Saul, and Radiolaria identifications and correlations are by Annika Sanfilippo.



Figure 1. Sandstone with *Turritella infragranulata pachecoensis* from locality 03CB5241 on the southwest flank of Cement Hill. A, View of rock surface. B, View of slab prepared by Skyler Phelps, Auburn. LouElla Saul identified and dated the fossils.

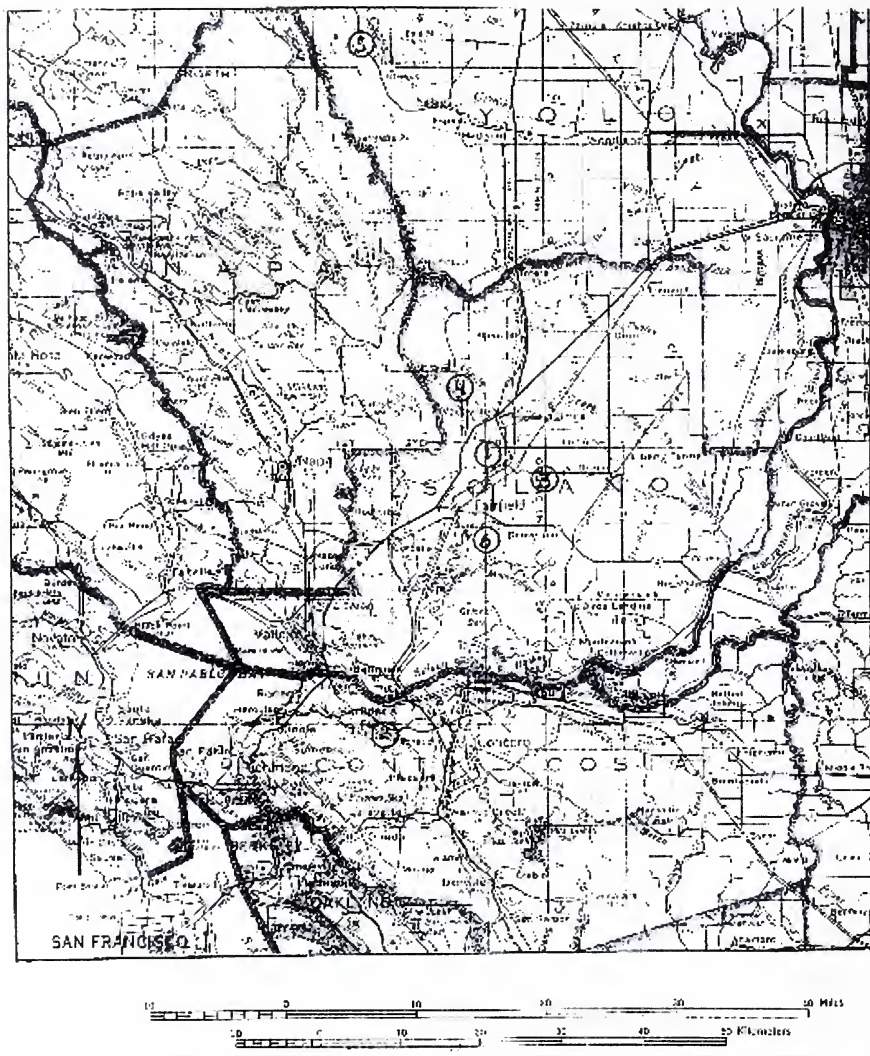


Figure 2. Map showing localities discussed in this report: (1) Lower Cement Hill area northeast of Fairfield; (2) Type area for Martinez Stage; (3) Vacaville Junction, Peabody Road, and Travis Field area; 4) Vaca Valley and Oakdale School area; and (5) Potrero Hills.

Previous work

The rocks that are the focus of this report were mapped by Weaver (1949) as Domengine Sandstone of Eocene age and by Sims and others (1973) as Late Cretaceous based partly on unpublished mapping by Exxon geologists Howard Sonneman and John Switzer. Part of the Sims and others map is shown in Figure 3. The dominance of Late Cretaceous rocks in the area, including the rocks regarded as Eocene by Weaver (1949), was supported by several collections of Late Cretaceous foraminifers identified by Chevron and Exxon paleontologists and virtually surrounding the lower Cement Hill area. The age of most of these samples was verified by Alvin Almgren from the original Chevron and Exxon slides. Except for the tiny outcrop of sandstone with Paleocene fossils, the existence of complexly folded and faulted Tertiary rocks would probably never have been discovered without the excavations that accompanied a preliminary geologic investigation for development of a housing area (Ristau, 1996).

New work in Cement Hill area

The current study area is part of a subdivision in the Fairfield North quadrangle for which grading commenced in 2002. Elevations within the subdivision development area vary from approximately 100 to 200 feet above mean sea level, with the 200-foot contour elevation targeted as the upper limit of grading for roadway and subdivision improvements.

Several samples of mudstone and siltstone from test pits and borings were sent to Alvin Almgren before grading began to determine the age of the rocks beneath the mapped alluvium. He provided ages of Late Cretaceous E and F-2 zones, late Paleocene E zone, and early Eocene C and B zone, all based on foraminifers (zones from Goudkoff, 1945 and Laiming, 1940). Because the test pits and borings were scattered in an area with only a small ledge of sandstone containing the *Turritella* exposed, the structural relationships of these samples could not be determined. The *Turritella* was examined by Louella Saul and determined to be *Turritella infragranulata pachecoensis* correlative with planktic foraminifer zone P4, the Martinez "stage" of Weaver (1953), and with other late Paleocene formations in California (Saul, 1983).

The sandstone with the *Turritella* dipped moderately to the east, similar to rocks that extended at least 35 miles north-northwest in an eastward dipping monocline (Figure 3). The rocks at lower Cement Hill could easily be interpreted as simply an extension of the monocline.

As grading began in 2002 on roads and housing pads, more and more sandstone, siltstone, mudstone, and shale above and below the *Turritella*-bearing sandstone were exposed. At one point in time, nearly 2,500 feet of what seemed like nearly continuous section was present in various outcrops throughout the site, with the Paleocene sandstone marker bed in the approximate center of the section. Many of the finer-grained rocks had foraminifers clearly visible on the rock surfaces, offering the possibility that this section might become the "Rosetta stone" for Paleocene rocks in central California, an area where rocks of this age are uncommon and generally sparsely fossiliferous. Accordingly, dozens of samples were collected for possible microfossil analysis. A preliminary "stratigraphic section" was pieced together based on the rocks exposed in the cuts (Figure 4). A conglomerate in shale overlying the sandstone with *Turritella* and the presence of a white sandstone similar to the Domengine Sandstone provided the incentive to speculate that the conglomerate above the *Turritella* beds might represent the beginning of Eocene deposition. Almost all of the assumptions for constructing this stratigraphic column proved to be incorrect.

As grading progressed, more nannoplankton samples were collected and sent to David Bukry. About one-half of the 40 samples have nannoplankton that provided ages for the rocks

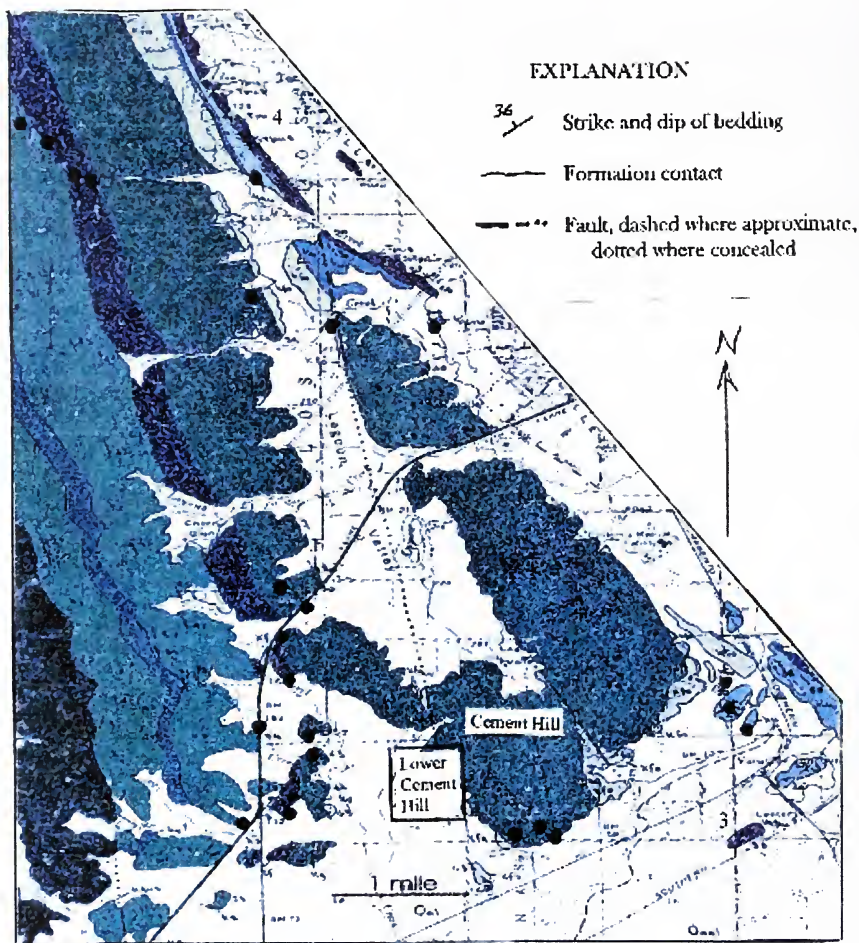


Figure 3. Part of the geologic map by Sims and others (1973) showing the geologic setting of the Cement Hill area. The area north-northwest of Cement Hill is a monocline with rocks of Cretaceous age dipping moderately to the east-northeast. Black dots show places where Chevron and Exxon geologists and E. Brabb collected Late Cretaceous foraminifers with ages confirmed by A. Almgren. Lower Cement Hill is where rocks significantly younger than Cretaceous were recently discovered.

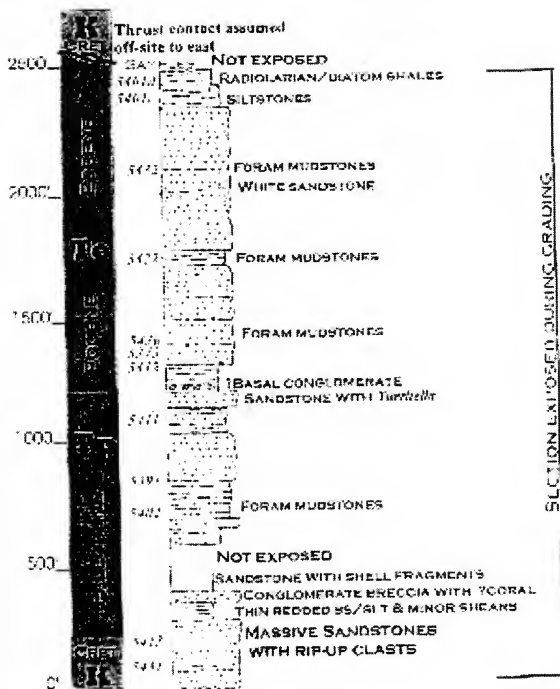


Figure 4. Original stratigraphic column for the lower Cement Hill area is based on limited paleontologic data and an assumption that faults in the section did not greatly displace the rocks. This column had to be completely revised when the rocks thought to be Eocene near the top of the column turned out to be partly overturned Late Cretaceous and Paleocene age and the rocks thought to be Paleocene below the *Turritella* bed turned out to be Eocene. Faulting with extensive displacement has disrupted the lower Cement Hill area into several different tectonic blocks.

(zones from Okada and Bukry, 1980; Bukry, 1991; and Bukry and others 1998). Additional samples for foraminifers were sent to Alvin Almgren and Kristin McDougall. The approximate location of the samples from preliminary scraper cuts, trenches, and other excavations are shown on figure 5. The rich character of the foraminifer faunas identified by K. McDougall was documented in the report by Brabb and others (2008, table 1). All the fossils were used to make a new geologic map, shown in figure 6. For convenience in discussing this complex area, the geology is divided into 6 blocks, A through F shown on figure 7. Almost all of the rocks uncovered in the Lower Cement Hill area are now concealed by concrete roads, curbs, sidewalks, house foundations, and fill.

Structural blocks in the area

Six structural blocks are bounded by extensively brecciated shear zones, some of which have been partly filled with calcite. At least two of the blocks are overturned. The blocks are discussed from East to West (also see Figure 7).

Block A. This block in the eastern portion of lower Cement Hill has about 20 feet of overturned and highly sheared, dark-gray to black shale and siltstone, with Late Cretaceous coccoliths, foraminifers, and the following radiolarians at localities 02CB5401D and E.: *Afens liriodes* Riedel and Sanfilippo, *Alievium superbum* (Squinabol), *Amphipyndax pseudoconulus* (Pessagno), *A. tylotus* Foreman(?), *Archaeodictyomitra lamellicostata* (Foreman), *Clathropyrgus titthium* Riedel and Sanfilippo, *Cryptamphorella conara* (Foreman), *Dictyomitra crassispina* (Squinabol)(?), *Lithomelissa hoplites* Foreman, *Myllocercion acineton* Foreman, *Pseudoaulophacus floresensis* Pessagno, *P. lenticulatus* (White), *Stichomitra asymbatos* Foreman, *Theocampe salillum* Foreman(?), *Theocapsomma comys* Foreman. Annika Sanfilippo believes these are correlative with the Late Cretaceous Campanian Stage, *Amphipyndax pseudoconulus* Zone of Riedel and Sanfilippo (1974) emended by Foreman (1977) as the *A. enesseffi* Zone. For additional reference, see the report by Sanfilippo and Riedel (1985). Most of the radiolarians from lower Cement Hill are illustrated on Plates 1 and 2. The shale with radiolarians also contains rare coccoliths of Late Cretaceous age.

The overturned rocks with Late Cretaceous fossils in Block A seemingly grade into a similarly-overturned 10-foot thick siltstone, sandstone, and glauconitic sandstone and a 70-foot thick siltstone containing CP4 late Paleocene coccoliths at locality 03CB5401C. These rocks are truncated by highly sheared siltstone in which the bedding is intensely deformed and distorted at the western boundary of Block A. The eastern boundary of Block A is concealed beneath alluvium but is assumed to be a fault because all the Cretaceous rocks uphill seem to be upright.

Foraminifers from the rocks with Late Cretaceous fossils in Block A were thought to be most likely Paleogene but could be as old as Cretaceous, according to K. McDougall. A. Almgren examined foraminifers from the same locality and believes that they are Late Cretaceous E zone. Similar black shale that weathers white and contains abundant diatoms, radiolarians, and foraminifers of Late Cretaceous age has been mapped by Exxon geologists along Peabody Road north of Vacaville Junction about 3 miles east of 02CB5401D and E (Figure 2, area 3) and along the west side of Vaca Valley northwest of Vacaville (Figure 2, area 4). This shale has been given the local name "Sacramento" shale by petroleum geologists. At those localities, discussed by Brabb and others (2008) and Almgren (1959, 1986), the black shale also contains a prolific foraminifer fauna correlative with the Campanian Stage and E zone of Goudkoff (1945), according to Almgren (1986).

Block B. Most of the rock in block B is massive brown sandstone about 350 feet thick. A white sandstone about 50 feet thick forms the top of this sequence and is probably at least part of the Domengine Sandstone mapped by Sims and others (1973) in the Vacaville Junction, Peabody Road and Travis Field areas east of Cement Hill (Figure 2 area 3). Locality 02CB5432 in the middle of the sequence contains early Eocene CP10/11 coccoliths.

The rocks of Block B strike predominantly north to northwest and dip steeply to the northeast. A prominent zone of highly sheared sandstone interpreted as a fault zone about 100 feet wide extends at least along the north-south extent of the outcrop area and marks the boundary between Blocks B and C.

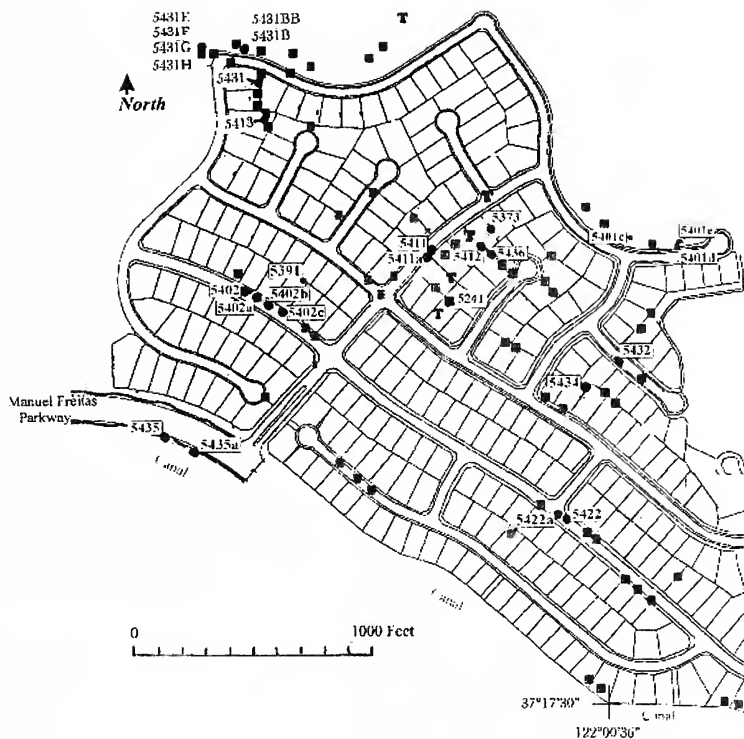


Figure 5. Subdivision layout along Manuel Freitas Parkway showing principal fossil locations relative to streets and lot lines. The gray squares indicate places where samples were collected but are barren of microfossils. The “T” shows places where *Turritella* sp. was observed and/or collected.

Block C. Block C consists mostly of at least 400 feet of well-bedded sandstone and siltstone. Several interbeds of greenish-gray mudstone and shale contain foraminifers and coccoliths of early Eocene age. However, strata at the base of the sequence contain the youngest floras, indicating that Block C is overturned. Shale and mudstone at localities 03CB5373 and 5434 contain early Eocene CP10 coccoliths, whereas localities 03CB5412 and 5436 contain early Eocene CP11 coccoliths. Locality 03CB5412 also contains a rich foraminifer fauna correlative with the late Penutian Stage to early Ulatisian Stage, according to K. McDougall. Localities 02CB5422 and 5422A from the middle part of Block C have CP10/11, undivided, coccoliths.

Bedding in Block C strikes nearly north and is overturned to the east. Several small-scale folds and faults are present within Block C, and other folds and faults are suspected.

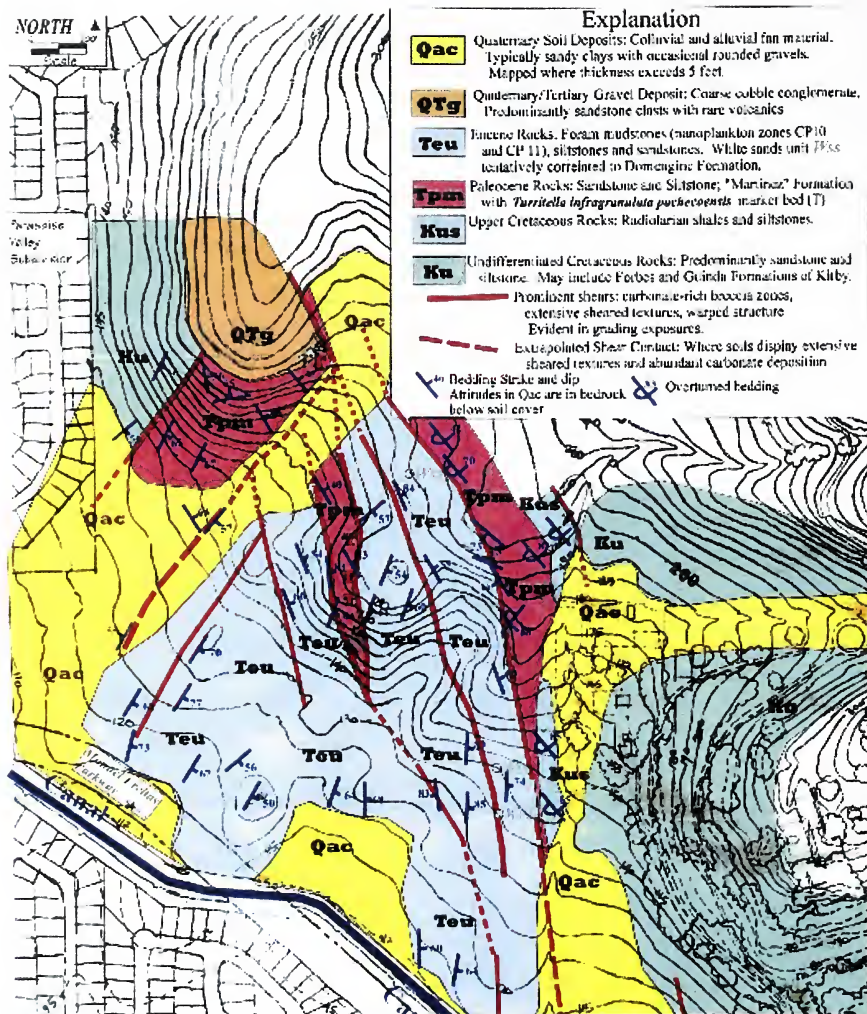


Figure 6. Revised geologic map for the lower Cement Hill area north of Manuel Freitas Parkway from extensive paleontologic, lithologic, and structural data.

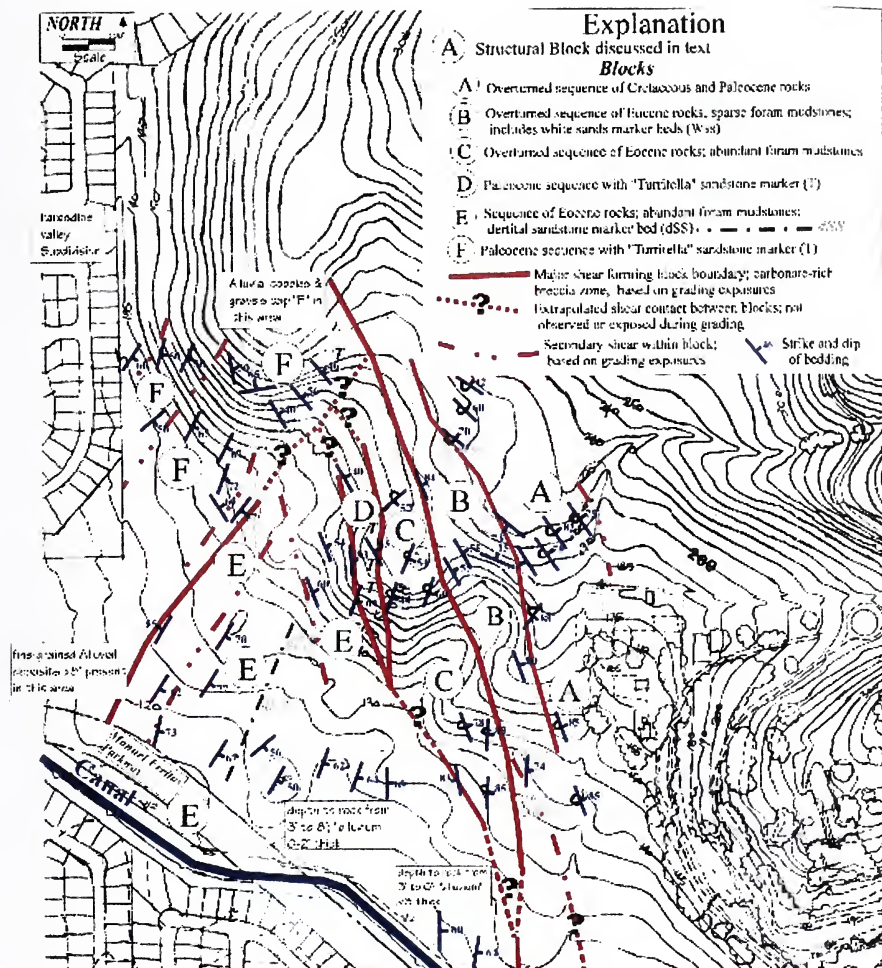


Figure 7. Division of the lower Cement Hill area into six structural blocks labeled A through F in order to discuss each block separately.

Block D. This block consists mainly of massive brown sandstone about 100 feet thick. Within this sandstone is a well-cemented 3-foot thick sandstone bed with abundant *Turritella infragranulata pachecoensis*. This bed was traced throughout the extent of Block D where it had to be removed or buried in order to create level building pads and streets.

The eastern part of Block D is a highly sheared and contorted mixture of sandstone and shale with fault surfaces dipping from 30 degrees to vertical. The fault zone brings rocks of Paleocene age in Block D against Eocene rocks in Block C. The western boundary of Block D consists of a 20- to 25-foot thick zone of sheared siltstone and mudstone with numerous crosscutting shears. Bedding is highly contorted and disrupted. The bedding in the remaining part of the block strikes northwest and dips moderately to the northeast.

Block E. The rocks in Block E are mainly well-bedded sandstone with many interbeds of siltstone, mudstone, and shale with a total thickness of at least 500 feet. One greenish-gray mudstone and glauconitic mudstone within Block E is about 200 feet thick and has localities 03CB5402, 5402A, 5402B, 5402C 03CB5391, 03CB 5411, 5411A and 03CB5412 with early Eocene CP10 coccoliths. Rich foraminifer faunas of early or middle Eocene age, late Penutian to early Ulatisian benthic foraminiferal stages, were found in these same samples, according to K. McDougall.

The rocks at the western boundary of Block E are not exposed but are covered with alluvium that has extensive shear zones and secondary carbonate extending in a northeast-southwest direction. We interpret these shears and carbonate as masking a major fault truncating Blocks C, D, and E.

Block F. Approximately 300 feet of laminated sandstone with interbeds of siltstone comprise the lower part of Block F in the northwest part of the lower Cement Hill area. Some sandstone is thicker-bedded and has rip-up clasts of mudstone at a few localities near the western edge of the property where the oldest beds were concealed by houses in the adjacent subdivision and alluvium during our work. The rocks strike predominantly northeast-southwest and dip fairly steeply to the southeast.

Localities 03CB5431B, 5431BB, 5431E, and 5431G from siltstones in the lower part of Block F yielded arenaceous foraminifers correlative with the Late Cretaceous F-1 zone of Goudkoff, according to A. Almgren. Localities 03CB5431F and 5431H have rare coccoliths of Late Cretaceous age.

The upper part of Block F consists mainly of about 500 feet of thickly bedded to massive sandstone with interbeds of siltstone. These rocks strike and dip in about the same direction as those in the lower part of the Block. A sandstone grit at or near the base of this unit contains fragments of mollusks and what seemed from a brief examination to be a coral, but the exposure was covered before the material could be collected. The contact between the sandstone grit and the underlying sandstone beds could be a disconformity or a fault.

Turritella infragranulata pachecoensi, was recovered from sandstone near the top of Block F. A sample containing foraminifers of late Paleocene E zone age was identified by A. Almgren from a test pit in the vicinity of the *Turritella*-bearing sandstone, but the rocks with the foraminifers could not be found after the hill was excavated so that the stratigraphic position of these fossils relative to the *Turritella* was not established.

Shear zones occur near the contact between the lower and upper units of Block F, but the similar attitudes above and below this shear zone and the presence of what may be a disconformity made us reluctant to divide the unit into separate blocks.

How do the blocks fit together?

Almost none of the rocks in the various blocks have distinctive marker beds that allow us to piece the blocks together to make a continuous section. The *Turritella*-bearing sandstone is present

in Blocks B and F but was not found in Block A. The white sandstone in Block B and the relative ages of coccoliths in various blocks allowed us to tentatively piece together a section (figure 8) with about 2,000 feet of largely sandstone with many siltstone, shale and mudstone inter-beds ranging in age from Late Cretaceous Campanian Stage to early Eocene CP11. Blocks A and D are not shown because at least some or all of the rocks are duplicated in Block F. However, the Cretaceous rocks in Block A are different in age from those in Block F, suggesting that more faulting or unconformities are present than we recognized. The presence of many additional shears than described and several small-scale folds should make readers cautious that the so-called section (Figure 8) is probably duplicated in part and even more complex in structure than we realized.

Can landsliding explain the structures observed?

The alluvium in the Lower Cement Hill area before grading had a somewhat hummocky appearance and is downhill from crescent-shaped valleys that could be landslide scarps, providing the possibility that the overturned beds and faulted blocks were produced by landsliding. The outcrops uphill from the part that was graded, however, are all Cretaceous rocks seemingly in place and not overturned. No rocks of Tertiary age were found uphill from the graded area. Moreover, no alluvium was mixed in with the overturned and faulted bedrock blocks as might be suspected if landsliding produced the mixed structure. We conclude that the structures seen in Lower Cement Hill were produced by tectonic forces, not landsliding. A glance at the regional structure north and south of lower Cement Hill (Figure 3) provides clues about the complicated structure. North of Vacaville for at least 35 miles, Cretaceous rocks are part of a monocline dipping moderately to the east. About 5 miles southeast of lower Cement hill, however, Paleocene and Eocene rocks have been folded into a broad anticline with nearly an east-west strike in the Potrero Hills (Figure 2, area 5, and Sims and others, 1973). This anticline and areas south of Potrero Hills are much more complex than previously mapped, as shown by Unruh and Hector (2007, fig. 2, reproduced on Figure 9 here). Their map was constructed from seismic reflection surveys and from oil well records. They believe that the thrust faults and other structures were produced by contractional folding between the bounding Greenville and Concord strike-slip faults, at least some of which occurred in the late Cenozoic. The lower Cement Hill exposures provide the first surface evidence to corroborate the complex structures inferred from subsurface information in this part of California.

Is the name Martinez Formation appropriate?

The lower Cement Hill localities are only a few tens of kilometers north of Martinez (Figure 1, area 2) where this formation was first named by Whitney (*in* Gabb, 1869, p. xiii) and considered to be Cretaceous. The subsequent evolution of the name is well described by Smith (1957, p. 130-135) and will not be repeated here. The term has been used mostly as a stage for rocks with Paleocene fossils, not as a lithologic unit. As Smith (1957, p. 134) points out, "no really satisfactory description of a type Martinez formation has ever been given." Therefore, the use of "Martinez Formation, restricted" on the map by Brabb, Sonneman and Switzer (1971) or "Martinez formation" by Sims and others (1973) is not good practice because of likely confusion with the Martinez Stage.

Weaver (1953) used the name Vine Hill sandstone as a substitute for Martinez Formation in the vicinity of Martinez. This glauconitic sandstone and minor siltstone has abundant mollusks including *Turritella pachecoensis* of Paleocene age indicating that it has similar lithology and is

correlative with the rocks at Cement Hill and Vaca Valley. However, enough differences in the stratigraphic succession and detailed lithology in the two areas warrant caution in extending the Vine Hill to the Cement Hill area.

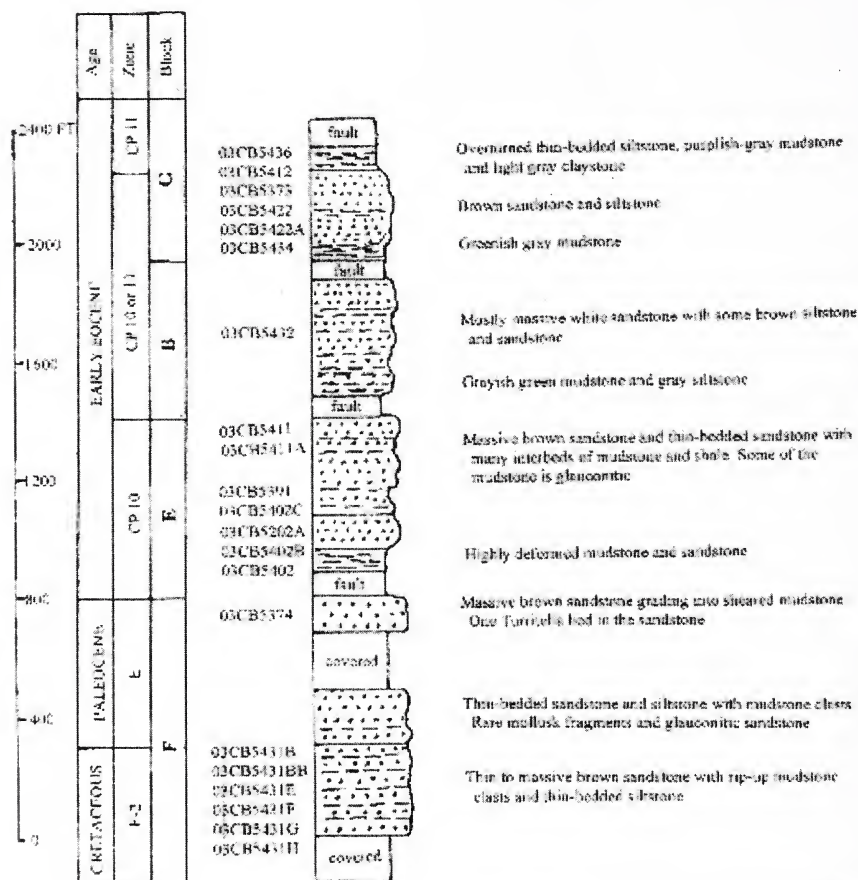


Figure 8. A new stratigraphic column for the lower Cement Hill area showing the different fault blocks, collecting localities, and an interpretation of how the faulted and in some places overturned blocks fit together. Unrecognized faulting and folding may further complicate this overview of the stratigraphic sequence

Conclusions

The discovery of a Paleocene index fossil in moderately dipping sandstone at the south end of a monocline of Cretaceous and Tertiary rocks led to the erroneous conclusion that the rocks with the fossil was part this monocline. Subsequent excavation of the rocks above and below the sandstone with Paleocene fossils led to the erroneous conclusion that lower Cement Hill must have the thickest fossiliferous Paleocene section in northern California. Documentation with coccoliths and other fossils that beds above and below the sandstone with Paleocene fossils are partly overturned Cretaceous and Eocene rocks has led to a completely different interpretation of the structure. Failure to recognize dislocations of a section by landsliding or faulting are common pitfalls in California, but errors in interpreting the Cement Hill section should serve as a reminder to paleontologists that complexly faulted sections are probably more common than anyone has realized.

Acknowledgments

We are grateful to Robert Tooby who provided unlimited access to the Cement Hill area during the entire period of this study. MCK Consulting provided extensive support and technical interest during the initial aspects of this investigation. Charles Powell II, U. S. Geological Survey, kindly arranged for LouElla Saul to examine the Paleocene gastropods. Skyler Phelps donated assistance and support for collecting and cutting large slabs of the *Turritella* beds. Wallace Kuhl Associates provided the subdivision base map used for determining the fossil sample collection localities. We are very grateful to managers and paleontologists with Unocal Company of California, Exxon Petroleum Company, and Chevron Petroleum Company for making samples and notes available for the Vaca Valley, Cement Hill, and Peabody road areas. Scott Hector, Paul Graham Drilling Company, and Jeff Unruh, William Lettis and Associates, kindly provided information about their work in the Potrero Hills.

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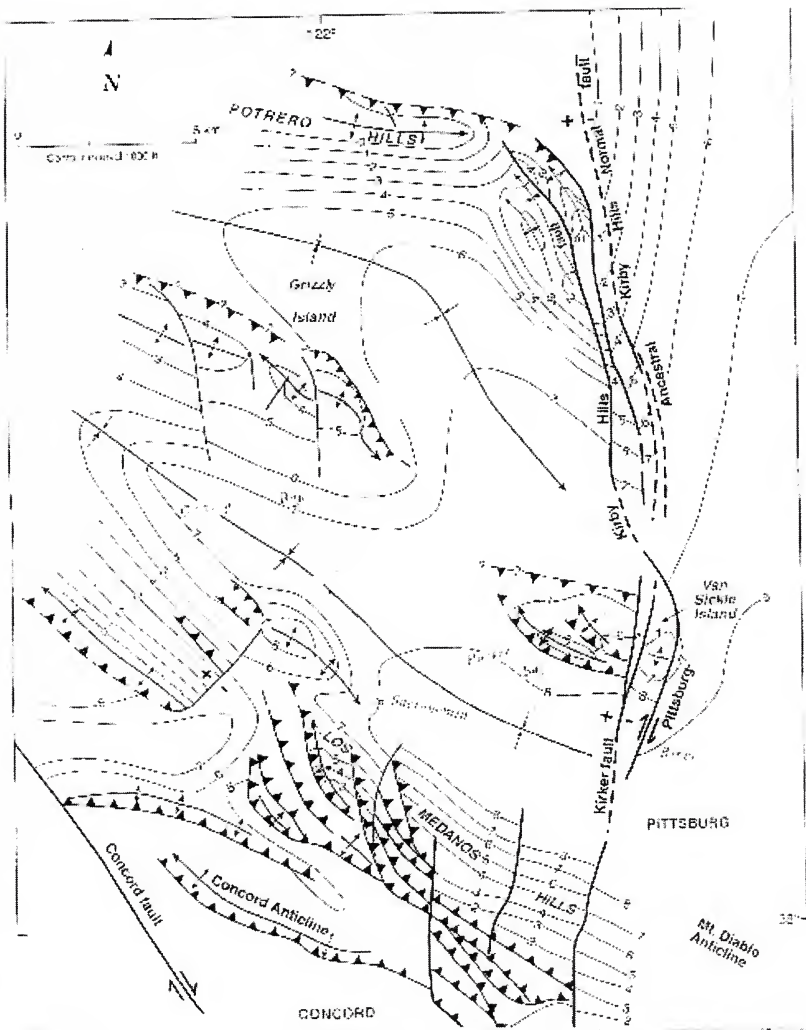


Figure 9. Structural contour map on top of the Eocene Domingine Sandstone in the Potrero Hills to Concord area. The northern part of this map is less than 5 miles (8 km) southeast of lower Cement Hill. Figure prepared by Jeff Unruh and Scott Hector (2007) from seismic reflection and oil well data. Permission to republish received from authors and the Pacific Petroleum Geologist Newsletter.

Plate 1

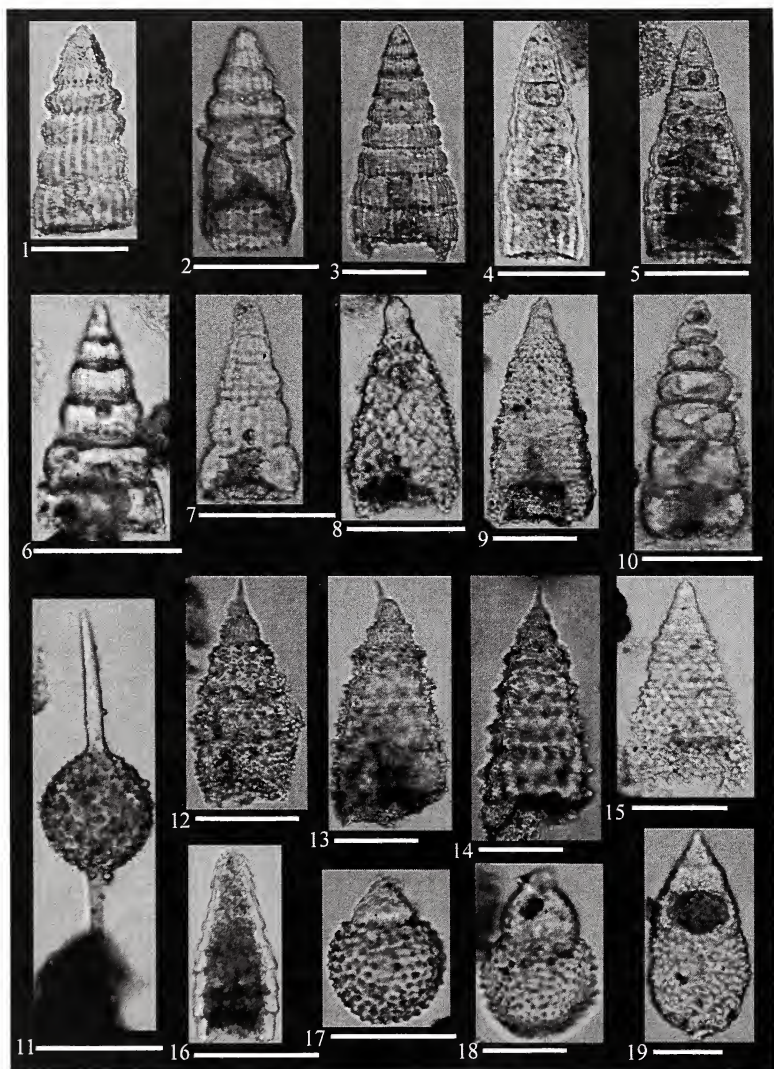


Plate 1

Codes after sample descriptions are slide designations and England Finder coordinates, respectively. Scale bars = 100 µm

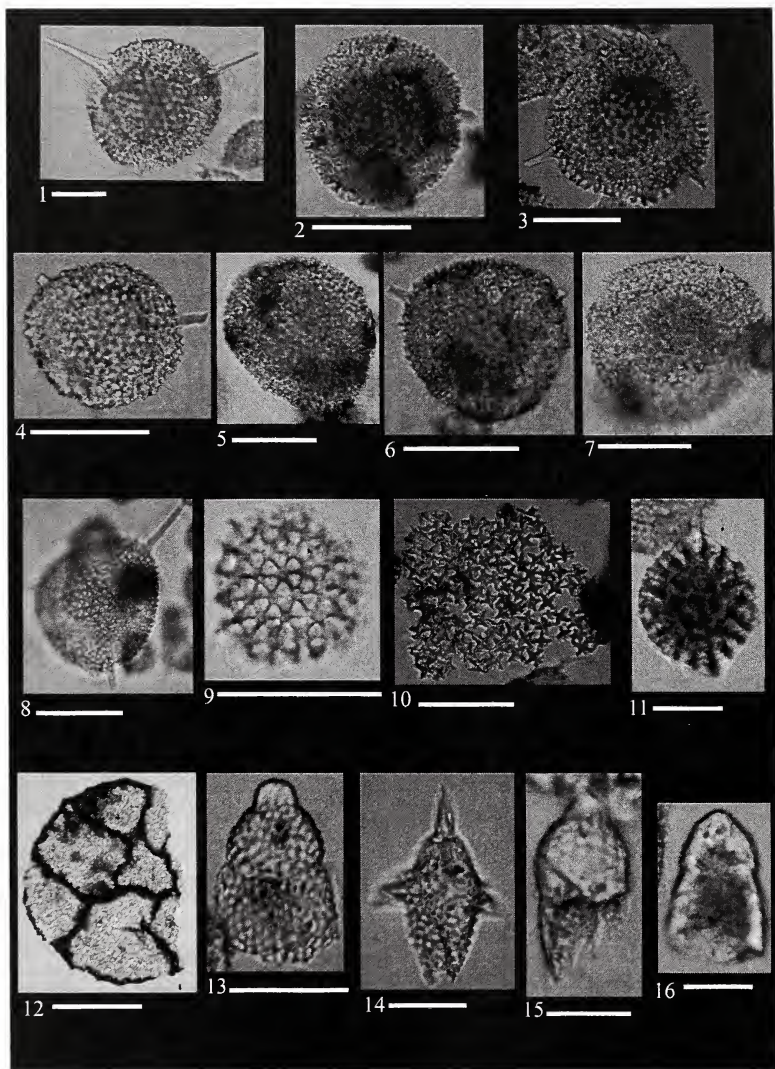
1. *Dictyomitra* sp., Sample 03-CB5401-D, Sl., P32/3
2. *Dictyomitra* sp., Sample 03-CB5401-D, Cs.1, R40/1
3. *Dictyomitra* cf. *D. multicostata* Zittel, Sample 03-CB5401-D, Sl., U3/0
4. *Dictyomita* cf. *D. regina* (Campbell and Clark), Sample 03-CB5401-F, Sl., E51/1
5. *Dictyomitra* cf. *D. multicostata* Zittel, Sample 03-CB5401-D, Sl.2, C35/1
6. *Dictyomitra* sp., Sample 03-CB5401-E, Sl., L44/3
7. *Dictyomitra* sp., Sample 03-CB5401-F, Sl., B40/4
8. *Amphipyndax* cf. *A. tylotus* Foreman, Sample 03-CB5401-D, Sl., H29/2
9. *Amphipyndax stocki* (Campbell and Clark), Sample 03-CB5401-F, Sl.1, O33/4
10. *Dictyomitra* cf. *D. koslova* Foreman, Sample 03-CB5401-D, Cs.2, N39/4
11. *Amphisphaera* cf. *A. minor* (Clark and Campbell), Sample 03-CB5401-D, Sl.2, B40/2
12. *Stichomitra* cf. *S. grandis* (Campbell and Clark), Sample 03-CB5401-D, Sl.2, A14/1
13. *Stichomitra* cf. *S. grandis* (Campbell and Clark), Sample 03-CB5401-D, Cs.1, W40/1
14. *Stichomitra* cf. *S. grandis* (Campbell and Clark), Sample 03-CB5401-D, Cs.2, W43/0
15. *Amphipyndax* sp., Sample 03-CB5401-F, Sl.1, V36/2
16. *Siphocampe altamontensis* (Campbell and Clark), Sample 03-CB5401-D, Sl.2, W30/0
17. *Cryptamphorella* cf. *C. conara* (Foreman), Sample 03-CB5401-D, Cs.2, K29/2
18. *Kuppelella* cf. *K. amphora* (Campbell and Clark), Sample 03-CB5401-D, Sl.1, Q16/3
19. *Cyrtocapsa* cf. *C. camp*i (Campbell and Clark), Sample 03-CB5401-F, Sl., L29/3

Plate 2

Codes after sample descriptions are slide designations and England Finder coordinates, respectively. Figs. 1-12 Scale bars = 100 µm, Figs. 13-16 Scale bars = 50 µm

1. *Pseudoaulophacus* sp., Sample 03-CB5401-D, Sl.2, B37/3
2. *Pseudoaulophacus lenticulatus* (White), Sample 03-CB5401-D, Cs.1, Q34/0
3. *Pseudoaulophacus floresensis* Pessagno, Sample 03-CB5401-D, Cs.1, V41/3
4. *Pseudoaulophacus lenticulatus* (White), Sample 03-CB5401-D, Cs.1, G41/4
5. *Pseudoaulophacus* sp., Sample 03-CB5401-F, Sl., W38/2
6. *Pseudoaulophacus* sp., Sample 03-CB5401-D, Cs.1, C16/0
7. *Pseudoaulophacus* sp., Sample 03-CB5401-E, Sl., P22/2
8. *Pseudoaulophacus floresensis* Pessagno, Sample 03-CB5401-D, Sl., U24/0
9. *Alievum superbum* (Squinabol), detail of triangular meshwork. Sample 03-CB5401-E, Sl., M46/4
10. Siliceous unknown pore structure, Sample 03-CB5401-D, Sl., J 26/4
11. *Stylosphaera* sp., Sample 03-CB5401-D, Sl.1, K30/0
12. Recrystallized foraminiferan fragment, Sample 03-CB5401-D, Cs.1, R29/0
13. *Kuppelella* sp., Sample 03-CB5401-D, Sl.2, W30/0
14. *Lithomelissa hoplites* Foreman, Sample 03-CB5401-D, Sl.2, B23/0
15. *Mylocercion acineton* Foreman, Sample 03-CB5401-D, Sl.1, U41/4
16. ?*Theocampe lispa* Foreman, Sample 03-CB5401-D, Sl., M54/1

Plate 2



ELLEN J. MOORE, TERTIARY MARINE MOLLUSKS, AND THE U. S. GEOLOGICAL SURVEY

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Ellen Louise James was born on February 6, 1925, in Portland, Oregon, the middle of three children of Thomas William James and Mildred P. James. Her father was a night watchman at a local department store and her mother stayed home and looked after the kids. Her childhood was spent in Portland, where she and her brother and sister attended the local elementary and high schools. Ellen collected her first fossils as a young high school student during one of the regular, usually monthly geologic field trips run by the Geological Society of the Oregon Country, which would meet in downtown Portland, and then car pool to a designated location. These fossils, and the excitement they ignited in Ellen, were the inspiration that led her into a long and successful career in paleontology.

After high school, her interest in geology and fossils continued as she attended Oregon State College (now OSU), where she received her Bachelor of Arts degree in Geology in 1946. Her paleontology professor was none other than Earl L. Packard, who had led the original field trip in Portland where she had found her first fossils. Following graduation, she worked for the Army Corps of Engineers, as well as at less exciting endeavors before realizing the need to return to graduate school to further advance herself. She received her Master of Science degree from the Department of Geography and Geology at the University of Oregon in 1950 with a thesis titled "A new Miocene marine invertebrate fauna from Coos Bay, Oregon." Her thesis advisor there was Ewart M. Baldwin.

Following graduation, she took the required civil service exam needed for employment by the U. S. government, and was subsequently offered a position with the U. S. Geological Survey in Washington, D.C. After a short stint in the Mineral Deposits Branch, she was able to transfer to the Paleontology and Stratigraphy Branch (P&S), with offices in the U.S. National Museum building where she worked for a number of different paleontologists. It was there that she had the opportunity to work with and along side of Wendell P. Woodring, an unbelievable dream come true for anyone interested in Cenozoic mollusks. This relationship developed into a lasting friendship and fondness for the man that lasted for many years, as evidenced by her memorial to Woodring published in 1992 by the National Academy of Sciences. If nothing else, Woodring was meticulously thorough in his investigations, and this work ethic must have been instilled in Ellen as well, based on the thoroughness of her later monographic studies on Tertiary marine mollusks.

While in Washington, Ellen had begun further study of the Astoria Formation fossils of her thesis work, which was mostly done on her own time, in the evenings and on weekends. This work eventually expanded into a major monograph published as USGS Professional Paper 419 in 1963 [1964]. Previously, in trying to decipher the identity of the Oregon Tertiary fossils described by

Timothy A. Conrad in the 1800s, she spent two months at the ANSP in Philadelphia and was able to recognize most of Conrad's type specimens.

Ellen had married a fellow USGS geologist in 1952, but when that relationship ended, she requested a transfer and was assigned to the Paleontology & Stratigraphy Branch in Menlo Park, California, the western headquarters of the Geological Survey, in 1959. Here she met George W. Moore, also a USGS geologist, and they were married on November 30, 1960, in Palo Alto. Neither of their two children (Leslie and Geoffrey) have followed their parents into geology, but have had successful careers of their own. George Moore died in an automobile accident on October 4, 2007.

If Ellen's first USGS assignment with the P&S Branch and Wendell Woodring at the USNM can be considered a stroke of good fortune, her transfer to Menlo Park was no less significant. Here, with Warren Addicott, and later Louie Marinovich, and a host of other paleontologists of various taxonomic persuasions, she was part of the most active group of paleontologists on the West Coast in many years. Menlo Park was THE center of Tertiary molluscan research and its reputation extended across the Pacific to Japan and Russia.

Although Ellen's list of publications numbers less than 40, many of them are significant contributions. Particularly useful, thoroughly documented and/or exquisitely illustrated are her study of Conrad's type specimens (1962), her monographs on Miocene and Oligocene faunas of the Astoria Formation (1963 [1964]), Pittsburg Bluff Formation (1976), and Lincoln Creek Formation (1984), her biostratigraphic studies on middle Tertiary molluscan zones (1984) and the Pillarian and Newportian molluscan stages (1987, with Warren Addicott), and a series of systematic studies (1983–1992) summarizing the fossil record of the "Tertiary Marine Pelecypoda of California and Baja California," published as chapters A through E in U. S. Geological Survey Professional Paper 1228, and continued with Chapters F and G on her internet web site at <http://www.cmug.com/chintimp/Tertiary.pelecypods.htm>. Ellen's publications also catered to the amateur fossil collector with profusely and well illustrated identification guides to local fossils of San Diego County, California (1968) and the Oregon coast (1971, 1994, 2000).

Ellen's career with the USGS lasted for 37 years, from 1950 to 1987, when she and her husband George retired from active service and moved to Corvallis, Oregon. Upon retirement, Ellen assumed Scientist Emeritus status with the USGS, followed by an appointment as Courtesy Research Associate in the Department of Geosciences at Oregon State University. In 2002, the Cordilleran Section of the Geological Society of America included an Invertebrate Paleontology session in her honor, chaired by Elizabeth Nesbitt. At the 41st Annual Meeting of the Western Society of Malacologists, held at the U. S. Geological Survey in Menlo Park, Ellen was honored with the Society's Award of Honor and an Honorary Life Membership in the Society in recognition of her lifetime achievements and contributions to the study of Tertiary marine mollusks of the Pacific Coast region. When so informed of the Society's intentions, Ellen responded thusly:

Thank you for honoring me ... at the Western Society of Malacologists' meeting in June. I found my first fossil mollusk during a Geological Society of the Oregon Country field trip when I was 13 years old, and this began my interest in paleontology. For all of my professional life in the U.S. Geological Survey I was fortunate to be paid for what I loved to do--study Tertiary marine mollusks. I am humbled by your honor. Ellen J. Moore

Information above was derived from a variety of sources, including discussions with Ellen, and my own personal recollections as well as those of her friends and colleagues, particularly Judy

Smith, Carole Hickman and Liz Nesbett. A short summary of Ellen's career is given in the Preface to her book, *Fossil shells from western Oregon – A guide to identification* (2000, pp. viii-ix).

New species named in honor of Ellen Moore:

Fulgoraria (Musashia) ellenmooreae Squires & Goedert, 1994 – Squires, R. L., and Goedert, J. L. 1994. A new species of volutid gastropod *Fulgoraria (Musashia)* from the Oligocene of Washington. *The Veliger*, 37(4): 400-408, figs. 1-8.

Tegula ellenae Addicott, 1966 – Addicott, W. O. 1966. New Tertiary marine mollusks from Oregon and Washington. *Journal of Paleontology*, 40(3): 635-646, fig. 1, pls. 76-78.

New taxa proposed by Ellen Moore:

Bivalvia

Acesta (Plicacosta) wilsoni Moore, 1984

Brachidontes (Brachidontes) cooperi Moore, 1983 (new name)

Felaniella (Felaniella) snavelyi Moore, 1976

Lima vedderi Moore, 1977

Modiolus addicotti Moore, 1984

Modiolus? (Modiolus?) clarki Moore, 1983 (new name)

Nucula (Leionucula) vokesi Moore, 1976

"Nuculana" epacris Moore, 1963 [1964]

Paramussium astoriana Moore, 1963 [1964]

Patinopecten oregonensis [Howe] *cancellus* Moore, 1963 [1964]

Saccella amelga Moore, 1963 [1964]

Saccella calkinsi Moore, 1963 [1964]

Gastropoda

Ancistrolepis jimgoederti Moore, 1984

"Bathybembix" hickmanae Moore, 1984

Cochliolepis? schoonerensis Moore, 1963 [1964]

Comitas? spencerensis Moore, 1963 [1964]

Cryptonatica pittsburgensis Moore, 1976

Liracassis Moore, n. gen.; Moore, 1963 [1964]

Musashia (Nipponomelon) shikamai Moore, 1984

Neverita (Glossaulax) jamesae Moore, 1963 [1964]

Ocenebra depoenis Moore, 1963 [1964]

Opalia (Dentiscala?) hertleini Moore, 1976

Perse pittsburgensis [Durham] *vernoniensis* Moore, 1976

Polinices canalis Moore, 1963 [1964]

Spirotropis calodius Moore, 1963 [1964]

Turritella pittsburgensis Moore, 1976

Scaphopoda

Dentalium (Rhabdus) schencki Moore, 1963 [1964]

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TEN-YEAR COMPARISONS OF MOLLUSCAN ABUNDANCES ON A VERTICAL SUBTIDAL TRANSECT AT THE EDGE OF SEA OF CORTEZ, CABO SAN LUCAS, BAJA SUR, MEXICO

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Marine Mollusca have been the subject of unusual, long-term comparisons, including central Sea of Cortez sites on the Baja Peninsula monitored annually by Bertsch (2008,) where, statistically, species diversity increased but population densities decreased throughout the sampling, 1992 to 2001. Additional latitudinal comparisons within Sea of Cortez detected no latitudinal gradient (Bertsch and Hermosillo, 2007). Very broad latitudinal comparisons of diverse intertidal invertebrates showed major differences along western North American shores (Sagarin and Gaines, 2002).

Long-term, detailed comparisons of particular subtidal plots are even more rare, but can detect even slow changes in abundances or sizes of animals and plants. In an underwater sanctuary where Sea of Cortez meets the Pacific at the southern tip of Baja, California, at Cabo San Lucas, Kitting established a subtidal photographic transect in 1998, of ~30 cm x 60 cm contiguous quadrats, arranged vertically to a depth of 13 m. In the present study, Carter used Kitting's slides and digital video of the quadrats to compare photographic samples from mid April, 1998, with our mid April, 2008 photographic samples. Kitting's additional, subjective comparisons at each of four seasons, throughout that decade, suggested no major fluctuations in these Mollusca then.

Transparency of the water (horizontal and vertical secchi depth) was measured to be up to 12 meters during the sampling. The vertical rock surface was largely shaded, with little algae and coral. The hypothesis was that some sessile individuals would tend to persist and grow, while other taxa would disappear or increase in abundance. Photographic observations tabulated abundance of larger Mollusca, including numerous "yellow umbrella snail" opisthobranchs (*Tylodina fungina*), "giant oyster" (*Hyotissa hyotis*), other mollusks, and other major invertebrates. Although these oyster shells often were encrusted with variable sponges, hydroids, barnacles, etc., sea fans were aquatic landmarks that helped seek the same individual oysters growing detectably from the previous decade. Detailed comparisons show evidence that diverse mollusks, especially oysters, including large specimens, tended to increase in abundance and range of depth distribution.

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WARM EXTRALIMITAL FOSSIL MOLLUSKS USED TO RECOGNIZE THE MID-PLIOCENE WARM EVENT IN SOUTHERN CALIFORNIA

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Abstract

Molluscan biostratigraphy for the California Pliocene is poorly developed. The presence of warm-water, southern extralimital species such as the gastropods *Crucibulum* (large tropical forms), several larger tropical species of *Conus*, and *Discotectonica* at several localities in southern California indicates warm, subtropical to tropical conditions in southern California for a short period in the Pliocene. The Pliocene was generally a time of cooling water temperatures along the northeastern Pacific coast from tropical condition during the Miocene to cooler interglacial and glacial conditions in the late Pliocene and early Pleistocene. Therefore, these extralimital, warm water mollusks are unusual and have not been found in other Pliocene deposits.

Studies based on microfossils have identified a short period of warm temperatures in the middle Pliocene that has been named the mid-Pliocene warm event, 3.3-3.15 m.y.a. Based on previous age and biostratigraphic data the deposits discussed herein and the warm-water extralimital taxa present, we suggest correlating these faunas with the well-dated mid-Pliocene warm event. This allows much more precise dating of these deposits. It is further hoped that this warm event can be used as a correlation tool for additional Pliocene faunas at other locations in the northwest Pacific as has been done with middle and late Pleistocene deposits in the same area.

Introduction

Representatives of tropical forms of the gastropod genera *Architectonica*, *Conus*, and *Crucibulum* are not usually found in the Pliocene fossil record of southern California. We report here the presence of specimens of one or more larger species of the genus *Conus*, tropical *Crucibulum*, *Discotectonica placentalis* (Hinds), and indeterminate *Discotectonica*, from 1) the San Diego Formation at the border locality in southwest San Diego County; 2) unnamed Pliocene deposits on San Clemente Island, California Channel Islands; 3) the "Pico" Formation in the Whittier Hills of Orange County; 4) the so-called "Santa Barbara Formation" at Rincon Point near the Ventura - Santa Barbara County line; and 5) in the Cebada fine-grained member of the Carega Sandstone in the Santa Maria District of northern Santa Barbara County (Figure 1). The paleogeography, paleoecology, and age for these faunas are examined in order to determine if a biostratigraphic unit can be determined, based on the biogeographic character state (i.e., southern – with southern extralimital taxa) of the fauna, that is internally consistent and can be recognized elsewhere in the Pliocene of California.

Tropical and subtropical mollusks were common in California during the Miocene (Addicott, 1970) and some are present at certain times during the Pleistocene (Powell and others, 2000). According to Addicott (1970) the Pliocene was a period of progressive climatic cooling and extralimital mollusks of tropical and subtropical affinities almost entirely disappeared from California by the end of the Pliocene. More recent work on the Pliocene climate using microfossils and outlined by Leroy and others (1999), show the Pliocene was a period of climatic change although the trend was towards progressive cooling.

- 4.9-4.3 Ma: Warmer deep water temperatures or a possible deglaciation event (Tiedemann and others, 1994)
- 4.5 Ma: First Pliocene cooling (Zagwijn, 1960; Suc and others, 1995)
- Generally warmer conditions for the rest of the lower Pliocene (Suc and others, 1995)
- 3.6 Ma: Temperatures decrease (Zagwijn, 1960; Suc and others, 1995) culminating in cold temperatures between 3.35 and 3.3 Ma.
- 3.3-3.15 Ma: Mid-Pliocene warming event (Leroy and Dupont, 1994; Tiedemann and others, 1994)
- 3.15-2.6 Ma: Cooling trend leading to late Pliocene glaciation (Leroy and Dupont, 1994; Tiedemann and others, 1994)
- 2.6 Ma: Start of northern hemisphere glaciation (Leroy and Dupont, 1994)

Addicott (1970) general comment of progressive cooling in the Pliocene is correct, the Pliocene was a time of cool temperatures off California. But a few fauna in southern California, previously referred to the late Pliocene, have been recognized as containing a few warm-water, southern extralimital molluscan taxa and these faunas are the focus of this paper.

Discussion

Biostratigraphy of the California Pliocene is at present poorly developed. Hopefully with the advent of precisely dated divisions of the Pliocene (ICS International Stratigraphic chart - <http://www.stratigraphy.org/chus.pdf>, retrieved 12/2008) a refined biostratigraphy can be established. Here we follow the ICS chart for the Pliocene, which suggests division of this epoch into the follow stages: Zanclean (lower Pliocene) 5.33-3.60 Ma, Placenzian (middle Pliocene) 3.60-2.59 Ma, Gelasian (upper Pliocene) 2.59-1.81 Ma (Lourens, et al., 2004; Figure 2). The two-fold division of the California Pliocene suggested by Vedder (1960) is not used.

Five sites/formations previously considered late Pliocene in southern and central California contain warm southern extralimital mollusks, particularly the genus *Discotectonica*, and are assumed to have been deposited during a period when water temperatures were warmer than today off the adjacent coast today. Each site is discussed below and relevant age, biostratigraphic, and ecologic data are presented in order to determine if they could have been deposited during the same narrow interval of time and if they can be correlated with the mid-Pliocene warm event. The sites are listed from south to north. No detailed stratigraphy or biostratigraphic is considered within each site/formation and stratigraphically distinct collections are lumped together for the purpose of this preliminary study. Further work is need at each individual site to determine biostratigraphic and paleoclimatic successions, where possible.

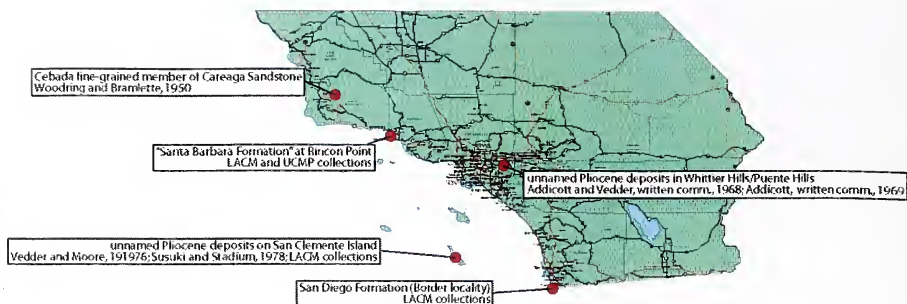


Figure 1. Map of the southern portion of California showing approximate location of fossil sites discussed in the text and pertinent references to the fossil faunas.

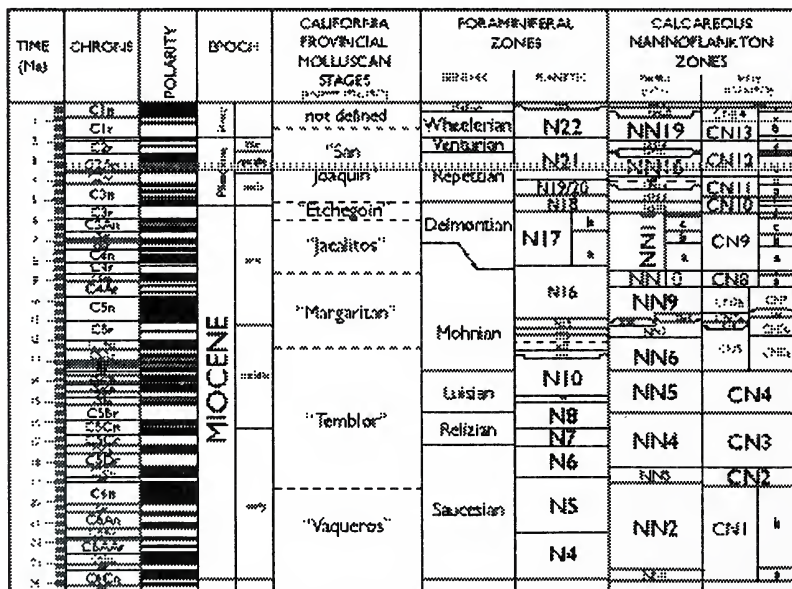


Figure 2. Neogene time scale modified from K. McDougall (written commun., 2006) shows with a gray bar indicating the position of the mid-Pliocene warm (3.3-3.15 m.y.a.) with relation to California provincial molluscan stages and California foraminifers and calcareous nannoplankton zones.

Border Park, San Diego County; San Diego Formation

A fauna of 204 molluscan taxa (99 bivalves, 80 gastropods, 22 polyplacophora, 3 scaphopods; Table 1) from southwestern-most San Diego County is here developed from collections at the Natural History Museum of Los Angeles County Invertebrate Paleontology section, (LACMIP) and personal field observations by Michael Vendrasco. This site is accessible at the time of writing (late 2008), but is due to be destroyed by construction of the Border Fence later this year or early next. Therefore documentation of this fauna is of the utmost importance.

Biostratigraphy – Arnold (1903, p. 57-58) recognized two biostratigraphic divisions of the San Diego Formation. A “lower horizon” characterized by the bivalves *Euvola stearnsii*, *Patinopecten healeyi*, the gastropods *Opalia varicostata anomala*, and *O. varicostata*, and an “upper horizon” characterized by the bivalve *Pecten bellus* (replacing *E. stearnsii*), rare *Patinopecten healeyi*, the gastropod *Crepidula princeps*, and the echinoid *Dendraster ashleyi* (Arnold, 1907). Deméré (1982) following Arnold’s lead, recognized a “lower” biostratigraphic unit characterized by *E. stearnsii*

Table 1. Faunal list from the San Diego Formation in the area of Border Field State Park, Imperial Beach, southwesternmost San Diego County. Faunal list compiled from Hertlein and Grant (1972; MS); also specimens identified by the senior author at LACMIP and field observations by the second junior author. ¹ indicates extinct taxa, ² indicates southern extralimital taxa.

Mollusca	
Bivalvia	
<i>Acila (Truncacila) castrensis</i> (Hinds, 1843)	Carpenter, 1864]
<i>Aligena diegoana</i> Hertlein & Grant, 1972 ¹	<i>Crenomytilus stearnbergi</i> Hettlein & Grant, 1972 ¹
<i>Anadara trilineata</i> (Conrad, 1856) ¹	[as <i>Mytilus (Crenomytilus) coalingensis</i>
<i>Anomia peruviana</i> d’Orbigny, 1846	<i>sternbergi</i> Hertlein & Grant]
<i>Anca sisquocensis</i> Reinhart, 1937 ¹	<i>Cryptomya californica</i> (Conrad, 1837) [also as <i>C.</i>
<i>Argopecten ventricosus</i> (Sowerby II, 1842) ¹ [as	<i>californica magna</i> Dall, 1921]
<i>Chlamys circularis</i> (Sowerby I, 1835)]	<i>Cumingia</i> cf. <i>C. californica</i> Conrad, 1837
<i>Axinopsida serricata</i> (Carpenter, 1864)	<i>Cyathodonta</i> sp.
<i>Barbatia (Fugleria) illota</i> (Sowerby, 1833) ²	<i>Cyclocardia occidentalis</i> (Conrad, 1855) ¹
<i>Basterotia hertleini</i> Durham, 1950 ¹	<i>Cyclocardia ventricosa</i> (Gould, 1850)
<i>Bornia (Temblornia) frankiana</i> Hertlein & Grant,	<i>Cyclopecten pernomus</i> (Hertlein, 1935) ²
1972 ¹	<i>Diplodonta orbella</i> (Gould, 1851)
<i>Brachiodontes adamsianus</i> (Dunker, 1857)	<i>Diplodonta sericata</i> (Reeve, 1850) ² [as <i>D. cornea</i>
<i>Cardiomya pectinata</i> (Carpenter, 1864)	(Reeve, 1850)]
<i>Chama arcana</i> Bernard, 1976 [as <i>C. pellucida</i>	<i>Donax gouldii</i> Dall, 1921
Broderip, 1835]	<i>Ensis myrae</i> Berry, 1953
<i>Chlamys hastata</i> (Sowerby II, 1842)	<i>Euvola stearnsii</i> Dall, 1878 ¹
<i>Chlamys hastata ellisi</i> Hertlein & Grant, 1972 ¹	<i>Gari (Gobraeus) fucata</i> (Hinds, 1845) [as
<i>Chlamys jordani</i> (Arnold, 1903) ¹	<i>Gobraeus edentula</i> (Gabb, 1869)]
<i>Chione</i> cf. <i>C. undatella</i> (Sowerby I, 1835)	<i>Glans carpenteri</i> (Lamy, 1922) [as <i>G.</i>
<i>Clinocardium nuttalli</i> (Conrad, 1837)	<i>subquadrata</i> (Carpenter, 1846)]
<i>Compsonyx subdiaphana</i> (Carpenter, 1864)	<i>Glycymeris (Axinola) grewingki</i> Dall, 1909 ¹
<i>Crassadoma giganteus</i> (Gray, 1825)	<i>Glycymeris (Axinola) septentrionalis</i>
<i>Crassinella pacifica</i> (C.B. Adams, 1852) [as	(Middendorff, 1849) [as <i>G. profunda</i> Dall,
<i>Astarte branneri</i> (Arnold, 1903)]	1878]
<i>Crenella decussata</i> (Montagu, 1808) [as <i>C. inflata</i>	<i>Gregariella coarctata</i> (Carpenter, 18957) [as
	<i>Gregariella chenui</i> (Récluz, 1842)
	<i>Here excavata</i> (Carpenter, 1857)

- Hiatella arctica* (Linnaeus, 1767)
Juliacorbula luteola (Carpenter, 1864)
Kellia suborbicularis (Montagu, 1803) [as *K. laperousii* (Deshayes, 1839)]
Leporimetis obesa (Deshayes, 1855) [as *Florimetis biangulata* (Carpenter, 1856)]
Limularia orcutti (Hertlein & Grant, 1972)¹
Luciniscia nuttalli (Conrad, 1837)
Lucinoma annulata (Reeve, 1850)
Leukoma staminea (Conrad, 1837)
Lyropecten cerrosensis (Gabb, 1869)¹
Macoma (Rexithaerus) indentata Carpenter, 1864
Macoma (Macoploma) medioamericana Olsson, 1842²
Mactromeris catilliformis (Conrad, 1867)
Mactromeris hemphilli (Dall, 1894)
Megapitaria squalida (Sowerby, 1835)²
Milneria minima (Dall, 1871)
Miltha xantusi (Dall, 1905)²
Miodontiscus prolongatus (Carpenter, 1864)
Modiolus (Modiollusia) rectus (Conrad, 1837)
Modiolus (Modiolus) sacculifer (Berry, 1953)
Myraeena veatchii (Gabb, 1866)¹ [and as *Ostrea vespertina* Conrad, 1854]

Nemocardium (Keenaea) centifilosum (Carpenter, 1864)
Nuculana (Jupetaria) taphria (Dall, 1896)
Nutricula cymata (Dall, 1913)
Nutricula tantilla (Gould, 1853)
Pandora (Pandorella) bilirata Conrad, 1855
Pandora (Heteroclidus) punctata Conrad, 1837
Panomya cf. *P. priapus* (Tilesius, 1822) [as *P.* cf. *P. beringiana* Dall, 1916]
Panopea abrupta (Conrad, 1849) [as *Panopea generosa* (Gould, 1850)]
Parvilucina tenuisculpta (Carpenter, 1864)
Patinopecten healeyi (Arnold, 1906)¹
Pecten bellus (Conrad, 1856)¹
Penitella penita (Conrad, 1837)
Periploma stenopa Woodring, 1938¹
Petricola carditoides (Conrad, 1837)
Pododesmus (Monia) macrochisma (Deshayes, 1839)
Pristes oblongus Carpenter, 1864
Protothaca (Calithaca) tenerrima (Carpenter in Gould & Carpenter, 1857)
Protothaca tenerrima alta (Waterfall, 1929)¹
Rocheortia tumida (Carpenter, 1864)

Saxidomus nuttalli Conrad, 1837
Securella kanakoffi Hertlein & Grant, 1972¹
Semele rubropicta (Dall, 1871) [syn. *S. ashleyi* Hertlein & Grant, 1972]
Septifer bifurcatus (Conrad, 1837)
Siliqua lucida (Conrad, 1837)
Solen (Ensisolen) sicarius Gould, 1850
Sphernia cf. *S. fragilis* (H. Adams & A. Adams, 1854) [as *S. cf. S. luticola* Valenciennes, 1846]
Swiftopecten parmeleei (Dall, 1898)¹
Tagelus californianus (Conrad, 1837)
Tellina (Peronidia) bodegensis Hinds, 1845
Tellina (Angulus) carpenteri Dall, 1900
Tellina (Tellinella) idae Dall, 1891
Tellina (Cadella) nuculoides (Reeve, 1854) [as *T. salmonea* (Carpenter, 1864)]
Thracia (Homoeodesma) trapezoides (Conrad, 1849) [as *T. kanakoffi* Hertlein & Grant, 1972]
Thyasira flexuosa (Montagu, 1803) [as *T. gouldii* (Philippi, 1845)]
Tivela stultorum (Mawe, 1823)
Trachycardium (Dallocardium) quadragenarium (Conrad, 1837)
Tresus nuttallii (Conrad, 1837)
Trigonulina pacifica Jung, 1996 [as *Ventricordia ornata* (Orbigny, 1842)]
Zirfaea cf. *Z. pilsbryi* Lowe, 1931

Gastropoda

Acanthinucella emersoni Hertlein and Allison, 1959¹
Acanthincuella spirata (Blainville, 1832)
Acmaea mitra Rathke, 1833
Alia tuberosa (Carpenter, 1864)
Amaea (Scalina) brunneopicta (Dall, 1908)
Asperiscala minutica (DeBoury, 1912)
Caesia cf. *C. grammatus* (Dall, 1917)¹
Callianax sp.
Calliostoma canaliculatum (Lightfoot, 1786)
Calliostoma coalingense catoteron Woodring, 1950¹
Calliostoma etchegoinense n. spp.?¹
Calliostoma gemmulatum Carpenter, 1864
Calyptrea filosa Gabb, 1866¹
Calyptrea inordata (Gabb, 1869)¹
Cancellaria arnoldi Dall, 1909¹
Cancellaria cooperi Gabb, 1865

Cancellaria fergusonii Carson, 1926
Cancellaria hemphilli Dall, 1909¹
Cancellaria sp.
Chlorostoma gallina multifilosa (Stearns, 1892)
Cidarina cidaris (Carpenter, 1845)
Comus (Chelyconus) californicus Reeve, 1844
Cranopsis cucullata (Gould, 1846)
Crassispira zizyphus (Berry 1940)
Crepidula aculeata (Gmelin, 1791)
Crepidula onyx Sowerby, 1834
Crepidula (Grandicrepidula) princeps Conrad, 1856¹
Crossata californica (Hinds, 1843)
Crucibulum spinosum (Sowerby 1824)
Diodora arnoldi McLean, 1964
Diodora aspera (Rathke, 1833)
Discotectonica cf. *D. placentalis* (Hinds, 1844)
Epitonium indianorum (Carpenter, 1864) [syn. *E. acrostephanus* Dall, 1908]
Epitonium tinctum (Carpenter 1864)
Euspira lewisii (Gould, 1847)
Euspira orbicularis Nomland, 1916¹
Fissurellidae bimaculata (Dall, 1871)
Glossaulax reclusianus (Deshayes, 1839)
Haliotis cf. *H. assimilis* Dall, 1878
Haliotis cf. *H. rufescens* Swainson, 1822
Haliotis walallensis Stearns, 1899
Halistylus pupoideus (Carpenter, 1864)
Homalopoma fenestrata "Bartsch" (Dall, 1919)
Homalopoma grippi (Dall, 1911)
Homalopoma paucicostatum (Dall, 1871)
Homalopoma radiatum (Dall, 1918)
Kelletia kelletii (Fobes, 1852)
Lirobittium cf. *L. asperum* (Gabb, 1861)
Lirobittium cf. *L. rugatum* (Carpenter, 1866)
Macrarenia diegensis McLean, 1964¹
Margarites pupillus (Gould, 1849)
Mangelia barbarensis Oldroyd, 1924
Mangelia? sp.
Maxwellia eldridgei (Arnold, 1907)¹
Megastrea turbanicus (Dall, 1910)
Megasurcula carpenteriana (Gabb, 1865)
Megathura crenulata (Sowerby, 1825)
Miceranellum crebricinctum (Carpenter, 1864)
Mitrella? sp.
Nassarius? sp.
Naticidae, indeterminate [as *Polinices* spp.]
Niveotectura funiculata (Carpenter, 1864)
Opalia monteeyensis (Dall, 1907)

Opalia varicostata Stearns, 1875¹ [syn. *O. varicostata anomala* Stearns, 1875]
Ophiostemma? sp.
Parviturbo acuticostatus (Carpenter, 1864)
Parviturbo stearnsii (Dall, 1918)¹ [syn. *P. s. quaylei* Hertlein & Grant, MS]
Pomaulax gibberosa (Dillwyn, 1817)
Pteropurpura festivus (Hinds, 1844)
Pupillaria aresta Berry, 1914
Scelidontoma bella (Gabb, 1865)
Sinezona rimuloides (Carpenter, 1865) [as *Coronadoa simonsae* Bartsch, 1946]
Skenea sp.
Solariella peramabilis Carpenter, 1864
Strioterebrum martini English, 1914¹
Tegula hemphilli Oldroyd, 1921¹
Terebra? sp.
Turcica coffea (Gabb, 1865 [syn. *T. brevis* Stewart, in Woodring and others, 1940(1941)])
Turritella cooperi Carpenter, 1864
Turritella hemphilli (Applin in Merriam, 1841)¹
Zonaria (Neobernaya) spadica (Swainson, 1823)

Polyplacophora (identified by M. Vandroscio, in manuscript)

Amicula n. sp.
Callistochiton palmaratus Dall, 1879
Callistochiton n. sp.
Lepidozона mertensii (Middendorff, 1847)
Lepidozона pectinulata (Carpenter in Pilsbry, 1893)
Lepidozона cf. *L. rothi* Ferreira, 1983
Leptochiton rugatus (Carpenter in Pilsbry, 1892)
Leptochiton nexus Carpenter, 1864
Lepidozона cf. *L. radians* (Pilsbry, 1892)
Lepidozона n. sp.
Mopalia aff. *M. imporcata* Carpenter, 1864
Mopalia cf. *M. swanii* Carpenter, 1864
Mopalia sp.
Nuttallina sp.
Oldroydia percrassa (Dall, 1894)
Placiphorella cf. *P. mirabilis* Clark, 1994
Placiphorella velata Carpenter
Stenoplax circumsenta Berry, 1956
Stenoplax conspicua (Pilsbry, 1892)
Stenoplax fallax (Carpenter, 1892)
Stenoplax cf. *S. heathiana* Berry, 1946
Tonicella cf. *T. lineata* (Wood, 1815)

Patinopecten healeyi, and *Opalia varicostata*, and an “upper” unit with *Pecten bellus*, the gastropod *Nucella lamellosa*, and *Dendraster ashleyi* as characteristic index species. Interestingly, *N. lamellosa* is an extralimital cool-water northern species that is not found south of Santa Cruz, Santa Cruz County, central California (Invertebrate Zoology and Geology section, California Academy of Sciences [CAS] collections), but there is some suspicion that its ecologic tolerances have changed over time (Campbell and Valentine, 1979). Gunther (1964) recognized two environmentally different cold-water benthic foraminiferal faunas from three sections along the southern slopes of Mount Soledad. Ingle (1967) using both benthic and planktonic foraminifers from the Pacific Beach section recognized a warm water, outer shelf assemblage in the lower part of the section and a cool water shallower assemblage in the upper part of his section. Later, Mandel (1973) examined planktonic foraminifers from exposures near the border and recognized a decidedly warm water, outer shelf assemblage. Unaware of the work of Ingle (1970) and following Gunther (1964), he guessed that his warm water fauna was younger than the section at Pacific Beach. Deméré (1982) pointed out that it is more likely that Mandel’s (1973) warm water fauna is correlative with the warm water facies at Pacific Beach and that the faunas of Gunther are likely younger. We speculate that their warm-water fauna at Pacific Beach also correlates with deposits at the Border locality.

Ecology – Using latitude data from extant species (Keen, 1971; Bernard, 1983; McLean, 1996; Coan and others, 2000; McLean, 2007) most of the species from the Border locality of the San Diego Formation have overlapping ranges between 32°N and 34°N, consistent with the latitude of the fossil localities (32.5°N). In addition, the bivalves *Cyclopecten pernomus* (2-29°N), *Macoma medcioamericana* (4-31°N), *Miltha xantusi* (25-26°N) and the gastropod *Discotectonica placentalis* (23-28°N; questionably identified here) are extralimital and occur only south of the fossil localities. *Argopecten ventricosa* (5-34°N), although not strictly extralimital, does represent a southern species with reproducing populations only occurring south of central Baja California (Coan and others, 2000). Populations north of Baja California are sporadic and may correlate with El Niño years, or periods of warmer water. Together, these species indicate water temperatures were warmer than off the adjacent San Diego coast at least in certain areas or perhaps during certain times of the year.

Depth data, from the same sources as above, show the vast majority of species have overlapping ranges between 20 and 30 m, with the bivalves *Donax gouldii* and *Penitella penita* occurring only shallower than 5 m and *Miltha xantusi* occurring deeper, between 55 and 80 m. It should be noted that *M. xantusi* has been found elsewhere in faunas significantly shallower than its modern depth range (for example see Powell, 2008) and its ecologic preferences may have changed over time. In any case, we assumed that deposition at the San Diego Border localities was between 20 and 30 m and that the other taxa washed in from adjacent areas.

Age – The precise age range of the San Diego Formation at the Border locality is unclear. Extinct mollusks includes the bivalves *Aligena diegoana*, *Anadara trilineata*, *Arca sisquocensis*, *Barbatia illota*, *Basterotia hertleini*, *Bornia frankiana*, *Chlamys hastata elli*, *C. jordani*, *Crenomytilus sternbergi*, *Euvola stearnsii*, *Glycymeris grewingki*, *Limularia orcutti*, *Lyropecten cerrosensis*, *Myrakeena veatchii*, *Patinopecten healeyi*, *Pecten bellus*, *Protothaca tenerrima alta*, *Securella kanakoffi*, *Swiftopecten parmeleei*, *Thracia kanakoffi*, and the gastropods *Acanthinucella*

emersoni, *Caesia* cf. *C. grammatus*, *Calliostoma coalingensis catoteron*, *C. ethegoinensis* n. spp.?, *Calyptrea filosa*, *C. inordata*, *Cancellaria fergusonii*, *C. hemphilli*, *Crassispira zizyphus*, *Crepidula princeps*, *Macrarenne diegensis*, *Maxwellia eldridgei*, *Opalia varicostata*, and *Turritella hemphilli*. Because *Aligena diegoana*, *Bornia frankiana*, *Chlamys hastata ellsii* (reported in LACM collection from the Pico Formation in the Simi Valley, Los Angeles County; L. Groves, LACM, personal commun., 2009), *Limularia orcutti*, and *Macrarenne diegensis* are all described from and restricted to the San Diego Formation they are of little use in refining the age of the Formation. The remainder of the extinct species indicate a Pliocene age for the San Diego Formation Border localities.

Deméré (1982; 1983) gives an age range of approximately 3.0 to 1.5 Ma [middle Pliocene (following division of the Pliocene from the International Stratigraphic Chart, 2004) to Early Pleistocene] for the formation. Barnes (1976, p. 332-334) assigned fossil vertebrates, mainly marine mammals from the formation to the Blancan North American provincial mammal age (4.75-1.81 Ma; <http://www.stratigraphy.org/geowhen/stages/Blancan.html>, retrieved 10/2/2008). Wagner and others (2001), using magnetic stratigraphy and land mammal biochronology for non-marine outcrops in the Chula Vista area, suggested a maximum age of about 3.6 Ma for their outcrops. Unpublished reports provided by George Kennedy (Brian F. Smith and Associates, San Diego, CA) on planktonic foraminifera and calcareous nannoplankton samples collected from the south side of Mt. Soledad (LACMIP Locality 17228) from sediment inside the bivalve *Patinopecten healeyii* and gastropod *Opalia varicostata* (as *O. v. anomala*) indicate a probable early Pliocene age (absolute age range 4.2 to 3.8 Ma; Boettcher, 2001; Kling, 2001). Therefore, the combined data currently available indicates a possible age range between 4.2 and 1.5 Ma for the San Diego Formation throughout its outcrop area.

Mandel (1973) interpreted strata from the Border locality as belonging to planktic foraminiferal zone N21. Recent work on planktonic foraminiferal stages assigns this zone an age of between 2.59-1.8 Ma (Gradstein and others, 2004). However, this age range does not allow for the warm water fauna collected by Mandel. As outlined above the late Pliocene/Early Pleistocene was a period of cooler temperatures and would not support the warm water fauna Mandell reported. New samples from the Border locality collected by M. Vendrasco and examined by J.P. Kennett correlate with California Margin planktonic foraminiferal zone 6 of Kennett and others (2000) and indicate a likely age of between 3.25 and approximately 2.5 Ma (M. Vendrasco, written commun., 2008).

San Clemente Island, California Channel Islands, Los Angeles County; unnamed Pliocene section

A small fauna of 15 mollusk taxa (6 bivalves, 8 gastropods, 1 scaphopod; table 2) was collected from a LACMIP locality 26322 on the east flank of the central part of San Clemente Island. A composite section about 30 m thick, without top or bottom exposed is found in the central part of the Island (Susuki and Stadum, 1978). The section is composed of a basal pebble to cobble conglomerate with scattered volcanic clasts followed by coarse grained biogenic detritus and shells, again with scattered volcanic clasts is exposed in this area (Susuki and Stadum, 1978).

Biostratigraphy - Other species reported from the Pliocene of central San Clemente Island include the bivalves *Anomia peruviana* d'Orbigny, *Chione?* sp., *Chlamys hastatus* Sowerby, *C. opuntia* Dall, *C. rubida* (Hinds), *Crassadoma giganteus* (Grey), *Crenella* sp., *Crenomytilus* cf. *C. coalingensis sternbergi* Hertlein, *Lima* cf. *L. hemphilli* Hertleina and Grant, *Modiolus* sp.,

Patinopecten healeyi (Arnold), *P. h. sanclementensis* Susuki and Stadium (a synonym of *P. healeyi*), *Pecten bellus* (Cornad), *P. cf. P. lecontei* Arnold, *Pododesmus macroschisma* Deshayes, *Pseudochama* sp., *Semele*? sp., and gastropods *Acmaea* n. sp.,? aff. *A. mitra* Rathke, *Aletes*? sp., *Alvinia* sp., *Astraea*? sp., *Bittium*? sp., *Calliostoma gemmulatum* Carpenter, C. n. sp., *Diodora arnoldi* McLean, *Fusitriton* sp., *Nitidiscala* cf. *N. indianorum* (Carpenter), *N. tinctum* (Carpenter), *Nitidiscala* n. sp.?, *Norrissia*? sp., *Opalia varicostata* Stearns, *Opalia* n. sp.?, *Pomaulax gradata* Grant and Gale (Vedder and Moore, 1976; Susuki and Stadium, 1978; LACMIP collections). Unfortunately, a detailed stratigraphic section has not been developed for the San Clemente Pliocene and it is beyond the scope of this preliminary study to do so. Therefore, all reported taxa from the Pliocene of San Clemente Island are grouped together for age and ecologic interpretations.

Table 2. Faunal list from unnamed Pliocene deposits from LACMIP locality 26322, identified by C. Powell, II at LACMIP, also reported by Susuki and Stadium (1978). ¹ indicates extinct taxa, ² indicates southern extralimital taxa.

Mollusca
Bivalvia

Chama arcana Bernard, 1976
Chama sp.
Cyclocardia cf. *C. ventricosa* (Gould, 1850) [juveniles]
Epilucina californica (Conrad, 1837)
Glycymeris cf. *G. growingki* Dall, 1909¹
Pseudocardium sp.¹

Gastropoda

Calliostoma annulatum (Lightfoot, 1786)
Cidarina cidaris (Carpenter, 1864) [as *Calliostoma* cf. *C. gemmulatum* (Carpenter, 1864)]
Discoetonic placentalis (Hinds, 1844) [as *A. cf. A. nobilis* Röding, 1798]²
Epitonium sp.
Fissurellidae, indeterminate [as *Fissurella volcano* Reeve, 1849; but not]
Haliotis sp.
Puncturella cooperi Carpenter, 1864
Serpulorbis squamigerus (Carpenter, 1857)

Scaphopoda

Dentalium pretiosum Sowerby, 1860

Ecology - Using latitudinal data from Keen (1971), Bernard (1983), McLean (1996), Coan and others (2000), and McLean (2007), the few extant species reported here show overlapping range zones between 33 and 34°N latitude, about the latitude of the fossil site (32.9°N). Based on the limited number of extant species present, the fossil collection represents the same water temperatures as off the adjacent coast today.

Depth data show all extant species to have overlapping ranges between about 40 and 50 m. The abundant biogenic detritus indicates a lack of terrigenous input, which occurs off California on the leeward side of the offshore islands (K. Lajoe, oral commun., 1990).

Age - Extinct species from the Pliocene of San Clemente Island, include the bivalves: *Chlamys opuntia*, *Glycymeris* cf. *G. grewingki*, *Lima* cf. *L. hemphilli*, *Patinopecten healeyi*, *Pecten bellus*, *P. cf. P. lecontei*, and the gastropods *Opalia varicostata* and *Pomaulax gradata*. These species have overlapping age ranges indicating a Pliocene age.

Whittier Hills, Los Angeles County; “Pico” Formation

A fauna of 111 mollusk taxa (44 bivalves, 67 gastropods; table 3) were collected from one site in the northern Whittier Hills, northeastern Los Angeles County by Cortez Hoskins in the 1960’s and identified by Warren O. Addicott and John G. Vedder (both United States Geological Survey [USGS] retired) in 1968 in an internal Evaluation and Report document (E&R). This site has since been developed and is no longer accessible, and was referred to the “Pico” Formation.

Biostratigraphy – The fauna above is from a single collection in an unrecorded section so no biostratigraphy is possible.

Ecology – Using latitude data from extant species (Keen, 1971; Bernard, 1983; McLean, 1996; Coan and others, 2000; McLean, 2007) most of the species from the Whittier Hills have overlapping ranges between 33°N and 34°N, consistent with the latitude of the fossil locality (approximately 33.6°N). In addition, the gastropods *Caesia cerritensis* (23–30°N; questionably identified here), *Discotectonica placentalis* (23–28°N, from Bahia Magdalena, on the outer coast of Baja California around the tip of the peninsula and into the Golfo de California, and south on

Table 3. Faunal list from the “Pico” Formation from the northern Whittier Hills (Ponoma College locality 136), Los Angeles County, California. Specimens identified by Warren O. Addicott and John G. Vedder, USGS E&R 0-68-9M, 3/1968. ¹ indicates extinct taxa, ² indicates southern extralimital taxa.

Mollusca

Bivalvia

Acila castrensis (Hinds, 1843)
Amiantis callosa (Conrad, 1837)
Anadara camuloensis (Osmont, 1904)¹
Anadara trilineata (Conrad, 1856) [including *A. t. canalis* (Conrad, 1856)]¹
Arca cf. *A. santamariensis* Reinhart, 1937¹
Argopecten cf. *A. invalidus* (Hanna, 1924)¹
Axinopsida serricata (Carpenter, 1864)
Barbatia pseudoillota Reinhart, 1937¹
Chama arcana Bernard, 1976 [as *C. pellucida* Broderip, 1835]
Chione fernandoensis English, 1914¹
Chlamys hastata (Sowerby, 1843)
Chlamys cf. *C. jordani* Arnold, 1903¹
Chlamys opuntia (Dall, 1898)¹
Chlamys rubida (Hinds, 1845) [as *C. hindsii* (Carpenter, 1864)]
Chlamys sp.
Compsoxyx subidaphana (Carpenter, 1864)
Crassadoma gigantea (Gray, 1825)
Crenomytilus coalingensis (Arnold, 1910)?¹

Diplodonta orbella (Gould, 1851)
Epilucina? sp.
Euvoia cf. *E. stearnsi* (Dall, 1879)¹
Gari (*Gabraeus*) *fucata* (Hinds, 1845) [as *G. edentula* (Gabb, 1869)]
Globivenus fordii (Yates, 1890)
Glycymeris sp.
Here excavata (Carpenter, 1857)
Lima sp.
Macoma cf. *M. calcarea* (Gmelin, 1791)
Mytilus trossulus Gould, 1850 [as *M. edulis* Linnaeus, 1758]
Nemocardium (*Keenae*) *centifilosum* (Carpenter, 1864)
Nucula sp.
Nuculana (*Jupiteria*) *taphria* (Dall, 1896)
Ostrea sequens Arnold, 1910¹
Pandora cf. *P. bilirata* Conrad, 1855
Panopea abrupta (Conrad, 1849)
Parvilucina approximata (Dall, 1901)
Patinopecten healeyi (Arnold, 1906)¹
Pecten bellus (Conrad, 1857) [as *P. hemphilli* Dall, 1878]¹

Pitar sp.
Pododermus macrochisma (Deshayes, 1839) [as
P. cepio (Gray, 1850)]
Saxidomus nuttalli Conrad, 1837
Swiftopecten parmelei (Dall, 1898)¹
Thracia (*Homoeadesma*) *trapezoides* Conrad,
 1849
Trachycardium (*Dallocardium*) *quadragenarium*
 (Conrad, 1837)
Varicorbula gibbiformis (Grant and Gale, 1931)¹

Gastropoda

Acteocina cf. *A. culcitella* (Gould, 1853)
Admete gracilior (Carpenter, 1869)
Alia tuberosa (Carpenter, 1864)
Amphissa versicolor Dall, 1871
Astiris cf. *A. gauspata* (Gould, 1850) [as *Mitrella*
 cf. *M. carinata gausapata* (Gould, 1850)]
Barbarofusus arnoldi Cossmann, 1903
 "Bittium" sp.
Bulla gouldiana Pilsbry, 1893
Caesia cf. *C. cerritensis* (Arnold, 1903)²
Caesia cf. *C. perpinguis* (Hinds, 1844)
Calicantharus humerosus (Gabb, 1869)¹
Calicantharus sp.
Callianax baetica (Carpenter, 1864)
Calliostoma cf. *C. gemmatum* Carpenter, 1864
Calliostoma supragranosum Carpenter, 1864
Calyptrea filosa (Gabb, 1866)¹
Cancellaria arnoldi Dall, 1909¹
Cancellaria hemphilli Dall, 1909¹
Capulus californicus Dall, 1900
Chlorostoma gallina (Forbes, 1852)
Cockerella conradiana (Gabb, 1866)
Conus (*Chelyconus*) *californicus* Reeve, 1844
Conus (*Lithoconus*) *fergusoni* Sowerby, 1873²
Conus (*Endemoconus*) *recurvus* Broderip, 1833²
Crassispira semiinflata (Grant and Gale, 1931)
 [as *Burchia redondoensis* (Burch, 1938)]
Crassispira zizyphus (Berry, 1940)
Crepidula aculeata (Gmelin, 1791)
Crepidula nummularia Gould, 1846
Crepidula (*Grandicrepidula*) *princeps* Conrad,
 1856¹
Crepidula sp.
Crepidatella dorsata (Broderip, 1834) [as *C.*
lingulata (Gould, 1846)]
Crossata cf. *C. californica* (Hinds, 1843)

Cryptonatica sp.
Dephnelia clathrata Gabb, 1865
Diodora arnoldi McLean, 1966 [as *D. inaequalis*
 (Sowerby, 1835)]
Discotectonica cf. *D. placentalis* (Hinds, 1844)²
Epitonium sp.
Erato sp.
Fusinus barbarensis (Trask, 1855)
Glossaulax reclusianus (Deshayes, 1839)
 "Gyrineum" *elsmerense* English, 1914¹
Hima cf. *H. mendicus* (Gould, 1849)
Iselica ovoidea (Gould, 1853) [as *I. fenestrata*
 (Carpenter, 1864)]
Lirobittium cf. *L. larum* Bartsch, 1911
Mangelia barbarensis Oldroyd, 1924
Mangelia spp.
Megasurcula cf. *M. carpenteriana* (Gabb, 1865)
Megathura cf. *M. crenulata* (Sowerby, 1825)
Musashia (*Nipponomelon*) *oregonensis* (Dall,
 1907)¹
 "Nassarius" *insculptus* (Carpenter, 1864)
Neptunea cf. *N. smirnia* (Dall, 1919)
Nodiscala cf. *N. spongiosa* (Carpenter, 1864)
Ocenebrina cf. *O. atropurpurea* (Carpenter,
 1865) [as *Ocenebra* cf. *O. interfossa clathrata*
 (Dall, 1919)
Ocenebrina cf. *O. barbarensis* (Gabb, 1865)
Ocenebrina sp.
Odostomia diegensis Dall and Bartsch, 1903
Polinices lewisii (Gould, 1847)
Roperea poulsoni (Carpenter, 1864)
Seila montereyensis Bartsch, 1907
Semibittium cf. *S. attenuatum* (Carpenter, 1864)
Sinum scopulosum (Conrad, 1849)
Solariella cf. *S. peramabilis* Carpenter, 1864
Strioterebrum martini English, 1914¹
Turricula sp.
Turridae, indeterminate
Turritella cooperi Carpenter, 1864
Zonaria cf. *Z. spadicea* (Swainson, 1823)

Polyplacophora

Callistochiton sp.

Scaphopoda

Dentalium neohexagonum Pilsbry and Sharp,
 1897

mainland Mexico to Guaymas, Mexico; questionably identified here), *Conus fergusoni* (4°S-25°N; questionably identified here), and *Conus recurvis* (5-25°N; questionably identified here) are extralimital and occur only south of the fossil locality. *Macoma calcaria* (44-71°N; questionably identified here) is a northern extra limital species that today occurs only north of the fossil locality. It is a common species in the middle Pleistocene and some older Pliocene and Pleistocene deposits in southern California and it is possible its ecologic tolerance may have changed, judging by the ecologic tolerances of associated species (Powell, unpublished data), or the specimens do not actually represent *M. calcaria* but a closely related with differing ecological preferences.

Depth data, from the same sources as above, show a bimodal depth data, with species such as *Amiantis callosa* (0-20 m), *Mytilus trossulus* (0-5 m), *Saxidomus nuttalli* (0-10 m), *Amphissa versicolor* (0-1 m; depth data from CAS wet collections examined by the senior author 10/1999), *Conus californicus* (0-30 m), and *Nassarius mendicus* (0-30 m) being found at water depths less than 30 m, whereas *Admete grailior* (60-250 m), *Conus recurvus* (40-160 m; Hanna and Strong, 1949), *Fusinus barbarensis* (50-350 m), *Nassarius insculptus* (50-530 m), and *Solariella perambilis* (50-350 m) occur only at depths greater than 40 m with some only deeper than 60 m. It is unclear from the faunal list where the taxa were deposited and it could be from anywhere between the intertidal zone (doubtful) to 60 m or greater (doubtful).

Age – Extinct species from the “Pico” Formation in the Whittier Hills include the bivalves *Anadara camuloensis*, *Anadara trilineata*, *Arca* cf. *A. santamariensis*, *Argopecten* cf. *A. invalidus*, *Barbatia pseudoillota*, *Chione fernandoensis*, *Chlamys* cf. *C. jordani*, *C. opuntia*, *Flabellipecten* cf. *F. stearnsi*, *Myrakeena veatchii*, *Patinopecten healeyi*, *Pecten bellus*, *Swiftopecten parmeleei*, *Varicorbula gibbiformis*, and the gastropods *Calicantharus humerosus*, *Calyptrea filosa*, *Cancellaria arnoldi*, *C. hemphilli*, *Crassispira zizyphus*, *Crepidula princeps*, *Psephaea oregonensis*, and *Strioterebrum martini*. These species have overlapping age ranges indicating a Pliocene age for this site.

Rincon Point/Rincon Hill, Santa Barbara/Ventura County line; “Santa Barbara” Formation

A composite fauna of 214 mollusk taxa (62 bivalves, 152 gastropods; table 4) has been collected from a number of sites in the general area of Rincon Point/Rincon Hill near the Santa Barbara/Ventura County line. Many of the best fossil localities are no longer accessible as they are dangerously close to US Highway 1. Upton (1951) measured a section 182 m (596') thick along US Highway 101, but on the east side of Rincon Hill a section approximately 290 m thick has been paced by the senior author. The faunal list here is from both sides of US 1, and along Rincon Road on the east side of Rincon Hill.

Biostratigraphy – Detailed biostratigraphy from the Rincon Point/Rincon Hill area is presently being investigated. Initial observations indicate the warm water gastropods *Crucibulum cyclopium* and *Discotectonica* have been found only in the upper part of the section. This suggests that the top of the section correlates with the mid-Pliocene warm and that the majority of the Rincon section is older. Neutral, that is temperatures similar to today off the adjacent coast, to cool water species dominate the lower part of the section and skew the ecologic interpretation of the fauna as a whole.

Ecology – This discussion is based on the composite faunal list compiled for the area and trends through the section are not possible at this time. Overall, the Rincon Point/Rincon Hill fauna shows overlapping geographic ranges between 33 and 34°N, using latitudinal data for extant species (Keen, 1971; Bernard, 1983; McLean and Grosiner, 1996; Coan and others, 2000; McLean,

2007). Only one southern extralimital taxa is present, *Discotectonica*, whereas numerous northern extralimital species occur: *Pandora wardiana* (47-57°N), *Patinopecten caurinus* (36-59°N), *Calyptraea fastigiata* (48-56°N), *Cylichnella alba* (37-71°N), *Lirabuccinum dirum* (37-56°N), and *Stylidium eschrichtii* (48-57°N). Future research will determine the stratigraphic significance of these species.

Table 4. Faunal list from the “Santa Barbara” Formation exposed in the vicinity of Rincon Point, on both sides of the Ventura and Santa Barbara County line, California. Specimens identified by the senior author at LACMIP and the third junior author from field observations. ¹ indicates extinct taxa, ² indicates southern extralimital taxa. ³ indicates northern extralimital taxa.

Mollusca	
Bivalvia	
<i>Acila castrensis</i> (Hinds, 1843)	<i>Nuculana</i> cf. <i>N. minuta</i> (Müller, 1776)
<i>Anomia?</i> sp.	<i>Nuculana</i> (<i>Jupiteria</i>) <i>taphria</i> (Dall, 1896)
<i>Axinopsida serricata</i> Carpenter, 1864	<i>Nuculana</i> sp.
<i>Cardiomya?</i> sp.	<i>Nutricula cymata</i> (Dall, 1913)
<i>Chlamys hastata</i> (Sowerby, 1843)	<i>Nutricula</i> cf. <i>N. lordi</i> (Baird, 1863)
<i>Chlamys jordani</i> (Dall, 1903) ¹	<i>Nutricula</i> cf. <i>N. tantilla</i> (Gould, 1853)
<i>Chlamys picoensis</i> (Waterfall, 1929) ¹	<i>Nutricula</i> sp.
<i>Chlamys opuntia</i> (Dall, 1898) ¹	<i>Pandora wardiana</i> A. Adams, 1860 ³
<i>Chlamys rubida</i> (Hinds, 1845)	<i>Panopea abrupta</i> (Conrad, 1849)
<i>Chlamys</i> sp.	<i>Parvilucina tenuisculpta</i> (Carpenter, 1864)
<i>Clinocardium?</i> sp.	<i>Parvilucina?</i> sp.
<i>Crassadoma giganteus</i> (Gray, 1825)	<i>Patinopecten caurinus</i> (Gould, 1850) ³
<i>Crenella decussata</i> (Montagu, 1808)	<i>Pecten bellus</i> (Conrad, 1857) ¹
<i>Crenella</i> sp.	“ <i>Pecten</i> ” sp. [flat valve]
<i>Cyathodoma pedroana</i> Dall, 1915?	Pectinidae, indeterminate
<i>Cyclocardia californica</i> (Dall, 1903) of Woodring and Bramlette, 1950 ¹	<i>Penitella</i> cf. <i>P. richardsoni</i> Kenbney, 1889 [as
<i>Cyclocardia</i> cf. <i>C. occidentalis</i> (Conrad, 1855) ¹	<i>Penitella</i> cf. <i>P. gabbii</i> (Tryon, 1863)]
<i>Donax gouldii</i> Dall, 1921	Pholadidae, indet. [includes <i>Penitella</i> sp.]
<i>Epilucina californica</i> (Conrad, 1837)	<i>Pododesmus macrochisma</i> (Deshayes, 1839)
<i>Flabellipecten?</i> sp.	<i>Pseudochama granti</i> Strong, 1934
<i>Gari?</i> sp.	<i>Semele</i> cf. <i>S. (Amphidesma) venusta</i> (Reeve, 1853)
<i>Hiatella?</i> sp.	<i>Solen sicarius</i> Gould, 1850
<i>Humularia prelamina</i> (Conrad, 1855) ² ¹	<i>Solen?</i> sp.
<i>Juliacorbula luteola</i> (Carpenter, 1864)	<i>Tellina</i> cf. <i>T. (Augulus) carpenteri</i> Dall, 1900
<i>Kellia</i> sp.	<i>Tellina</i> (<i>Augulus</i>) <i>modesta</i> (Carpenter, 1864)
<i>Leptopecten latiauratus</i> (Conrad, 1837)	<i>Trachycardium</i> (<i>Dallocardia</i>) <i>quadragenarium</i> (Conrad, 1837)
<i>Luciniscia nuttalli</i> (Conrad, 1837)	<i>Tresus?</i> sp.
<i>Lucinoma annulatum</i> (Reeve, 1850)	Veneridae, indeterminate
<i>Macoma nasuta</i> (Conrad, 1837)	
<i>Macoma</i> sp.	
<i>Modiolus</i> cf. <i>M. rectus</i> (Conrad, 1837)	Gastropoda
<i>Modiolus?</i> sp.	<i>Acanthinucella spirata</i> (Blainville, 1832)
<i>Mysella</i> sp.	<i>Acanthina?</i> sp.
<i>Mytilus</i> sp.	<i>Acmaea mitra</i> Rathke, 1833?
<i>Mytilidae</i> , indeterminate	<i>Acmaea?</i> sp.
	<i>Acteocina</i> cf. <i>A. culcitella</i> (Gould, 1853)
	<i>Acteocina harpa</i> (Dall, 1871)

- Admete* cf. *A. californica* (Dall, 1908)
Admete gracilior (Carpenter, 1869)
Alia carinata (Hinds, 1844)
Alia tuberosa (Carpenter, 1864)
Alvinia sp.
Amphissa reticulata Dall, 1916
Amphissa versicolor Dall, 1871
Amphissa sp.
Antiplanes catalanae (Raymond, 1904)
Asstyris gausapata (Gould, 1850)
Balcis sp.
Boreotrophon cf. *B. bentleyi* Dall, 1908
Boreotrophon multicostatus (Eschscholtz, 1829)
Boreotrophon pedroanus (Arnold, 1903) [also as
Trophon stuarti praecursor Arnold, 1903]
Boreotrophon cf. *B. stuarti* (Smith, 1880)
Borsonella cf. *B. merriami* (Arnold, 1903)
Caecum sp.
Caesia perpinguis (Hinds, 1844)
Caesia cf. *C. rhinetes* Berry, 1853
Calicantharus fortis (Carpenter, 1866)¹
Calicantharus sp.
Callianax cf. *C. baetica* (Carpenter, 1864)
Callianax biplicata (Sowerby, 1825)
Calliostoma canaliculatum (Lightfoot, 1786)
Calliostoma gemmulatum Carpenter, 1864
Calliostoma sp.
Cancellaria arnoldi Dall, 1909
Cancellaria crawfordiana (Dall, 1891)
Calyptraea fastigiata Gould³
Cancellaria arnoldi Dall, 1909¹
Cancellaria cf. *C. tritonidae* (Gabb, 1866)¹
Cerithiopsis pedroana Bartsch, 1907? [as *C.*
carpenteri Bartsch, 1911?]
Cerithiopsis sp.
Chlorostoma montereyi Kiener, 1850
Clathurella canfieldi Dall, 1871
Cockerella cf. *C. cymodoce* (Dall, 1919)
Cockerella sp.
Conidae, indeterminate
Comus (Chelyconus) californicus Reeve, 1844
Cranopsis cf. *C. cucullata* (Gould, 1846)
Crassispira seminiflata (Grant and Gale, 1931)
Crassispira zizyphus Berry, 1940
Crassispira sp.
Crepidula aculeata (Gmelin, 1791)
Crepidula nummaria Gould, 1846
Crepidula cf. *C. onyx* Sowerby, 1834
Crepidula perforans (Valenciennes, 1846)
Crepidula (Grandicrepidula) princeps (Conrad,
1856)¹
Crepidatella dorsata (Broderip, 1834)
Crossata californica (Hinds, 1843)
Crucibulum cf. *C. cyclopium* Berry, 1969²
Cryptonatica affinis (Gmelin, 1791)
Cylichna cf. *C. alba* (Brown, 1827)
Cylichna? sp.
Diodora arnoldi McLean, 1966
Diodora aspera (Rathke, 1833)?
Discotectonica cf. *D. placentalis* (Hinds, 1844)²
Discurria cf. *D. insessa* (Hinds, 1842)
Engina sp.
Epitonium cf. *E. sawinae* (Dall, 1903)
Epitonium tinctum (Carpenter, 1864) [identified
by H. DuShane, 12/12/1974]
Epitonium sp.
Euspira pallida (Broderip & Sowerby, 1829)
Exilioidea rectirostris (Carpenter, 1864)
Exilioidea? sp.
Fusinus cf. *F. barbarendis* (Trask, 1855)
Fusinus sp.
Fusitriton oregonensis (Redfield, 1846)?
Garnotia adunca (Sowerby, 1825)
Glossaulax reclusianus (Deshayes, 1839)
Granulina margaritula (Carpenter, 1857)
Haliotis sp.
Hima mendicus (Gould, 1849) [including *H. m.*
cooperi (Forbes, 1852)]
Hipponix tumens Carpenter, 1864
Homalopoma luridum Dall, 1885
Homalopoma panciostatum (Dall, 1871)
Homalopoma sp.
Kelletia kelleitii (Forbes, 1852)
Kelletia? sp.
Kurtzia? sp.
Lacuna? sp.
Lirobittium attenuatum (Carpenter, 1864)
Lirobittium sp.
Lirobuccinum dirum (Reeve, 1846)
Lirularia succincta (Carpenter, 1864)
Lirularia sp.
Littorina kenaeae Rosewater, 1978 [as *L. planaxis*
Philippi, 1847]
Littorina sp.
Lottidae, indeterminate
Lottia sp.
Lucapinella callomarginata (Dall, 1871)
Mangelia hexagona Gabb, 1865

Margarites pupillus (Gould, 1849)
Margarites sp.
Maxwellia eldridgei (Arnold, 1907)¹
Maxwellia cf. *M. gemma* (Sowerby, 1879)
Maxwellia santarosana (Dall, 1905)
Megastraea undosa (Wood, 1828)
Megasurcula carpenteriana (Gabb, 1865)
Megasurcula stearnsiana (Raymond, 1904)
Mitra idae (Melville, 1893)
Mitrella? sp.
"Nassarius" insculptus (Carpenter, 1864)
Naticidae, indeterminate
Neptunea tabulata (Baird, 1863) [including as *N. hawleyi* (Carson, 1926)]
Ocenebrina aspera (Baird, 1863)
Ocenebrina cf. *O. beta* (Dall, 1919)
Ocenebrina foveolata (Hinds, 1844)
Ocenebrina cf. *O. lurida* (Middendorff, 1848)
Ocenebrina squamulifera (Carpenter, 1868)
Ocenebrina sp.
Odostomia spp.
Ophioidermella cf. *O. fancheriae* (Dall, 1903)
Ophioidermella incisa (Carpenter, 1864)
Ophioidermella cf. *O. inermis* (Reeve, 1843)
Ophioidermella cf. *O. mercedensis* (Martyn, 1914)¹
Ophioidermella sp.
Polinices? sp.
Pomaulax gibberosa (Dillwyn, 1817)
Promartynia pulligo (Gmelin, 1791)
Pteropod, indeterminate
Pteropurpura cf. *P. macroptera* (Deshayes, 1839)
Pteropurpura trialata (Sowerby, 1834)
Pteropurpura vokesae Emerson, 1964
Puncturella sp.
Rhodopetoma? sp.
Rissonia sp.
Scabrotrophon cf. *S. clarki* McLean, 1996
Scabrotrophon cf. *S. maltzani* (Kobelt & Küster, 1878)
Scabrotrophon? sp.
Seila montereyensis Bartsch, 1907
Semibittium quadrifilatum (Carpenter, 1864)
Serpulorbis squamigerus (Carpenter, 1857)?
Solanella peramabilis Carpenter, 1864
Stylidium eschrichtii (Middendorff, 1849)
Tegula cf. *T. aureotincta* (Forbes, 1852)
Tegula sp.
Terebra pedroana (Dall, 1908)
Tricola? sp.
Turbonilla sp.
Turridae, indeterminate
Turritella cf. *T. cooperi* Carpenter, 1864
Turritella gonostoma hemphilli Merriam, 1941, of Woodring and Bramlette, 1950¹
Turritella cf. *T. teglandae* Merriam, 1941¹
Volvullela cylindrica (Carpenter, 1864)
Zonaria spadicea (Swainson, 1823)

The vast majority of taxa from the Rincon Point/Rincon Hill area have overlapping depth ranges between about 20 and 40 m with *Donax gouldii* (0-5 m), *Modiolus rectus* (0-15 m), *Solen sicarius* (0-1 m), *Amphissa versicolor* (0-1 m), *Littorina planaxis* (0-1 m), *Lucapinella callomarginata* (0-1 m), occurring shallower, and *Pandora wardiana* (40-200 m), *Pseudochama granti* (46-256 m), *Admete gracilior* (60-250 m), *Antiplanes catalinae* (90-270 m), *Boreotrophon bentleyi* (100-350 m), *Bonsonella merriami* (70-290 m), *Exiloida rectirostris* (60-800 m), *Fusinus barbarensis* (50-350 m), *Neptunea tabulata* (50-250 m), *Ophioidermella fancheriae* (50-200 m), and *Scabrotrophon clarki* (100-210 m) occurring deeper. Because of the lack of stratigraphic control in this preliminary note these species from outside the presumed depth zone where the fauna, as a whole, was deposited are not considered significant. Mid-shelf water depths are supported by Cronin and others (1983) who studied ostracodes from the Rincon Point section along US Highway 101 and characterized the fauna as one from an inner to middle shelf environment.

Age – Previously exposures at from the Rincon Point/Rincon Hill area were considered late Pliocene or early Pleistocene (Upton, 1951; Dibblee, 1966; Cronin and others, 1983) based on their correlation with the Santa Barbara Formation in Santa Barbara. Extinct species from this area include the bivalves *Chlamys jordani*, *C. picoensis*, *C. opuntia*, *Cyclocardia californica*, *C. cf. C. occidentalis*, *Humilaria prelamina*, *Pecten bellus*, and the gastropods *Calicantharus fortis*, *Cancellaria arnoldi*, *C. cf. C. tritonidae*, *Crassispira zizyphus*, *Crepidula princeps*, *Maxwellia*

eldridgei, *Ophiidermella* cf. *O. mercedensis*, *Turritella gonostoma hemphilli*, and *T. cf. T. teglandae*. Characteristic Pliocene index-species such as *Patinopecten healeyi* and *Opalia varicostata* are missing. In addition, most of the extinct species present occur in the Pliocene and Pleistocene. The occurrence of *Cancellaria arnoldi*, *Turritella gonostoma hemphilli*, and *T. cf. T. teglandae* indicate a Pliocene age as their known occurrences are restricted to the Pliocene. But their range zones are not well documented and *T. teglandae* is questionably identified here. Still we considered this area as Pliocene based on the above *Cancellaria* and *Turritella* occurrences, but the age is questioned.

Santa Maria District, Santa Barbara County; Cebada fine-grained Member of the Careaga Sandstone

Description of the formation and fauna of the Cebada fine-grained Member of the Careaga Sandstone (Table 5) is from Woodring and Bramlette (1950). The Careaga Sandstone ranges in thickness from 15 to 430 m (50' to 1425') is underlain by Foxen Mudstone and overlain by the Graciosa coarse-grained Member and Paso Robles Formation where the upper member is absent.

Faunas similar to the Cebada Member are found in the underlying Foxen Mudstone or older Sisquoc Formation and in the overlying Graciosa coarse-grained Member. Almost three-quarters of the specimens, were found at only one or two localities, with unusually good preservation: Fugler Point and the dump of an old asphalt mine on the south slope of Graciosa Ridge. The shells at both localities are preserved in tar sand or asphalt. Elsewhere, fossils from the Cebada Member are mostly casts and molds.

Biostratigraphy – According to Woodring and Bramlette (1950) all the most widespread species, namely *Anadara trilineata*, *Cryptomya* cf. *C. californica*, *Lucinoma* cf. *L. annulata*, *Modiolus* cf. *M. capax*, *Nucella taphria*, *Myrakeenea veatchii* (= *Ostrea vespertina* of Woodring and Bramlette, 1950), *Panopea* cf. *P. abrupta*, *Patinopecten healeyi*, *Protothaca* cf. *P. tenerrima*, *Solen perrini*, and *Caesia moraniana* occur in the Cebada fine-grained Member and also in the younger Graciosa coarse grained member of the Careaga Sandstone. In addition, all except *Nuculana* occur in the older Foxen Mudstone or in the still older upper Sisquoc Formation or in both. *Dosinia ponderosa diegoana*, *Lyropecten cerrosensis*, *Nuculana taphria*, *Petricola* cf. *P. buwaldi*, *Yoldia* cf. *Y. supramontereyensis*, *Cancellaria rapa perrini*, *Ophiidermella graciosa*, and *Strioterebrum martini* were found in both members of the Careaga Sandstone, or in undifferentiated Careaga strata, but not in older formations. The southern extralimital gastropod *Discotectonica* is restricted to this member.

Extinct species present in the underlying Foxen Mudstone and not in the Careaga Sandstone include *Nuculana orcutti*, *Mytilus* cf. *M. coalingensis*, *Swiftopecten parmelei etchegoini*, *Ranella* cf. *R. elsmmerense*, and the echinoid *Merrimaster* cf. *M. perrini* (Weaver). It is unclear if these species are stratigraphically or ecologically significant, but with further study they might be used to help develop a biostratigraphy for the California Pliocene.

Ecology – Overall, the Cebada fine-grained Member fauna shows overlapping geographic ranges between 34 and 35°N, using latitudinal data for extant species (Keen, 1971; Bernard, 1983; McLean, 1996; Coan and others, 2000; McLean, 2007) consistent with the latitude of the fossil localities. In addition, there are a number of northern extralimital species (*Macoma brota*, *Nuculana cultuuta*, *Panomya priapus*, *Siliqua alta*, *Calliostoma ligatum*, and *Calyptraea fastigiata*), but only one southern extralimital taxa, *Discotectonica* and several species have their northernmost end point of their range at or near the latitude of the fossil site (*Argopecten ventricosus*,

Calliostoma gemmulatum, and *Crepidula aculeata*). It is assumed that the northern and southern extralimital species do not occur in the same bed, but detailed biostratigraphy has not been performed at this time.

Table 5. Faunal list from the Cebada fine-grained member of Careaga Sandstone in the Santa Maria District, Santa Barbara County, California. Faunal list from Woodring and Bramlette (1950[1951]).

¹ indicates extinct taxa, ² indicates southern extralimital taxa, ³ indicates northern extralimital taxa.

Mollusca	
Bivalvia	
<i>Acila</i> cf. <i>A. (Truncacila) castrensis</i> (Hinds, 1844)	Carpenter, 1864
<i>Anadara trilineata</i> (Conrad, 1856)	<i>Macoma</i> cf. <i>M. nasuta</i> (Conrad, 1837) [as <i>M. n. kelseyi</i> Dall, 1900]
<i>Arca santamariensis</i> Reinhart, 1937 ¹	<i>Macoma</i> cf. <i>M. (Psammacoma) yoldiformis</i> Carpenter, 1864
<i>Arca sisquocensis</i> Reinhart, 1937 ¹	<i>Mactromeris</i> cf. <i>M. catiliformis</i> (Conrad, 1867)
<i>Argopecten</i> cf. <i>A. ventricosus</i> (Sowerby, 1842)	<i>Mactromeris</i> cf. <i>M. hemphilli</i> (Dall, 1894)
[as <i>A. cf. A. circularis</i> (Sowerby, 1835)] ²	<i>Miodontiscus</i> cf. <i>M. prolongatus</i> (Carpenter, 1864)
<i>Barbatia pseudoillota</i> Reinhart, 1937 ¹	<i>Modiolus</i> cf. <i>M. capax</i> (Conrad, 1837)
<i>Chama</i> cf. <i>C. arcana</i> Bernard, 1976 [as <i>C. cf. C. pellucida</i> Broderip, 1835]	<i>Mya</i> sp.
<i>Chlamys hastata</i> (Sowerby, 1843)	<i>Myrakeenea veatchii</i> (Gabb, 1866) [as <i>Ostrea vespertina</i> (Conrad, 1854)] ¹
<i>Clinocardium</i> cf. <i>C. meekianum</i> (Gabb, 1866) ³	<i>Nuculana (Jupiteria) cellulita</i> (Dall, 1896)
<i>Compsomyx</i> cf. <i>C. subdiaphana</i> (Carpenter, 1864)	<i>Nuculana (Jupiteria) penderi</i> (Dall and Bartsch, 1910) [as <i>Saccella redondoensis</i> (Burch, 1944)]
<i>Crenella</i> cf. <i>C. decussata</i> (Montagu, 1808)	<i>Nuculana (Jupiteria) taphria</i> (Dall, 1896)
<i>Crenomytilus</i> cf. <i>C. coalingensis</i> (Arnold, 1910) ¹	<i>Nutricola</i> cf. <i>N. tantilla</i> (Gould, 1853)
<i>Cryptomya</i> cf. <i>C. californica</i> (Conrad, 1837)	<i>Pandora</i> cf. <i>P. (Heteroclidus) punctata</i> Conrad, 1837
<i>Cumingia californica</i> Conrad, 1837	<i>Panomya</i> cf. <i>P. priapus</i> (Tilesius, 1822) [as <i>P. cf. P. beringianus</i> Dall, 1916] ³
<i>Cyclocardia californica</i> (Dall, 1903) ¹	<i>Panopea</i> cf. <i>P. abrupta</i> (Conrad, 1849) [as <i>P. cf. P. generosa</i> Gould, 1850]
<i>Diplodonta</i> sp.	<i>Parvilucina</i> cf. <i>P. tenuisculpta</i> (Carpenter, 1864)
<i>Dosinia ponderosa diegoana</i> Hertlein and Grant, 1972 ¹	<i>Patinopecten healey</i> (Arnold, 1906) ¹
<i>Euvola stearnsii</i> (Dall, 1878)? ¹	<i>Pecten bellus</i> (Conrad, 1857) [as <i>P. hemphilli</i> Dall, 1878] ¹
<i>Gari</i> cf. <i>G. (Gobraeus) californica</i> (Conrad, 1849)	<i>Penitella penita</i> (Conrad, 1837)
<i>Glans carpenteri</i> (Lamy, 1922) [as <i>G. subquadrata</i> (Carpenter, 1864)]	<i>Petricola</i> cf. <i>P. buwaldi</i> Clark, 1915 ¹
<i>Glycymeris</i> sp.	<i>Petricola</i> cf. <i>P. carditoides</i> (Conrad, 1837)
<i>Irusella</i> cf. <i>I. lamellifer</i> (Conrad, 1837)	<i>Pododesmus macroschisma</i> (Deshayes, 1839)
<i>Kellia suborbicularis</i> (Montagu, 1803) [as <i>K. laperousii</i> (Deshayes, 1839)]	<i>Protothaca</i> cf. <i>P. staleyi</i> (Gabb, 1866) ¹
<i>Limaria</i> cf. <i>L. hemphilli</i> (Hertlein and Strong, 1946)	<i>Protothaca</i> cf. <i>P. (Callithaca) tenerrima</i> (Carpenter, 1857)
<i>Lituyapecten diller</i> (Dall, 1901) ¹	<i>Pycnodonte erici</i> (Hertlein, 1929) ¹
<i>Lucinica nuttallii antecedens</i> (Arnold, 1907)	<i>Saccella orcutti</i> (Arnold, 1907) ¹
<i>Lucinoma</i> cf. <i>L. annulatum</i> (Reeve, 1850)	<i>Saxidomus</i> cf. <i>S. nuttalli</i> Conrad, 1837
<i>Lyropecten cerrosensis</i> (Gabb, 1866) ¹	<i>Semele</i> cf. <i>S. rubropicta</i> Dall, 1871
<i>Macoma</i> cf. <i>M. brota</i> Dall, 1916	
<i>Macoma</i> cf. <i>M. (Rexithaerus) indentata</i>	

Siliqua cf. *S. alta* Broderip and Sowerby, 1829 [as *S. cf. S. media* (Sowerby, 1839)]
Solena perrini Clark, 1915¹
Sphenia cf. *S. laticola* (Valenciennes, 1846) [as *S. cf. S. globula* Dall, 1919]
Swiftopecten parmeleii s.s. (Dall, 1898)¹
Tellina cf. *T. (Peronidia) bodegensis* Hinds, 1845
Tellina cf. *T. (Tellinella) idae* Dall, 1891
Tellina cf. *T. (Angulus) modesta* (Carpenter, 1864) [as *T. cf. T. buttoni* Dall, 1900]
Thracia cf. *T. (Homaeodesma) trapezoides* Conrad, 1849
Trachycardium cf. *T. (Dallocardium) quadragenarium* (Conrad, 1837)
Tresus cf. *T. nuttallii* (Conrad, 1837)
Yoldia cf. *Y. supramontereyensis* Arnold, 1908¹

Gastropoda

Acteocina cf. *A. culcitella* (Gould, 1853)
Admete gracilior (Carpenter, 1869)
Alia tuberosa (Carpenter, 1864), variety
Amphissa cf. *A. versicolor* (Dall, 1878)
Astyrus gausapata (Gould, 1850)
Balcis cf. *B. micans* (Carpenter, 1864)
Barbarofusinus? cf. *B. ? arnoldi* (Cossmann, 1903)
Barleeia cf. *B. acuta* (Carpenter, 1864) [as *B. marmorea* (Carpenter, 1864)]
"Bittium" *casmaliense* Bartsch, 1911¹
"Bittium" *casmaliense arnoldi* Bartsch, 1911¹
Boreotrophon multicostatus (Eschscholtz, 1829)
Caecum (Micranellum) crebricinctum (Carpenter, 1864)
Caesia cf. *C. fossatus* (Gould, 1849)
Caesia moraniana (Martin, 1914)¹
Calicantharus fortis angulata (Arnold, 1907)¹
Callianax cf. *C. baetica* Carpenter, 1864
Callianax pycna Berry, 1935 [as *O. bicipitata* (Sowerby, 1825), slender variety]¹
Calliostoma coalingense caloteron Woodring in Woodring and Bramlette, 1950[1951]¹
Calliostoma cf. *C. gemmulatum* Carpenter, 1864
Calliostoma cf. *C. ligatum* (Gould, 1849)
Calliostoma virginicum (Conrad, 1873) [this species (and the following) is from the Miocene of Virginia and not known from California. It is misidentified here, but not illustrated and what the name represents is unclear]
Calliostoma cf. *C. virginicum* (Conrad, 1873) [see above]

Calliostoma sp.
Calyptraea cf. *C. fastigiata* Gould, 1846
Calyptraea radians (Lamarck, 1822)¹
Cancellaria arnoldi Dall, 1909¹
Cancellaria crawfordiana (Dall, 1891)
Cancellaria fergusonii Carson, 1926 [as *C. cf. C. tritonidea* Gabb, 1866; syn. *C. santa-mariniae* Carson, 1926]¹
Cancellaria hemphilli Dall, 1909¹
Cancellaria lipara Woodring in Woodring and Bramlette, 1950[1951]¹
Cancellaria rapa Nomland, 1917¹
Cancellaria rapa perrini Carson, 1926¹
Ceratostoma foliata (Gmelin, 1791) [as *Jaton* cf. *J. carpenteri* (Dall, 1899)]
Cidarina cidaris (Adams, 1864)
Clathromangelia variegata (Carpenter, 1864) [angular variety of Willett *fide* Woodring and Bramlette, 1950[1951]]
Cockerella conradiana (Gabb, 1866)
Cranopsis cucullata (Gould, 1846)?
Crepidula aculeata (Gmelin, 1791)
Crepidula coei Berry, 1950 [as *Crepidula* cf. *C. excavata* (Reeve, 1859)]
Crepidula nummaria Gould, 1846
Crepidula (Grandicrepidula) princeps Conrad, 1856¹
Crepidatella cf. *C. dorsata* (Broderip, 1834) [as *C. cf. C. lingulata* (Gould, 1846)]
Crucibulum cf. *C. scutellatum* (Wood, 1824) [as *C. cf. C. imbricatum* (Sowerby, 1828)]²
Cryptonatica affinis (Gmelin, 1791) [as *C. aleutica* Dall, 1919, small variety]
Cylichnella cf. *C. attonsa* Carpenter, 1864
Cymakra gracilior (Tryon, 1884) [as *Mitramorpha intermedia* Arnold, 1903, variety]
Cymatosyrinx cf. *C. empyrosia* (Dall, 1899)
Demondia californianus (Conrad, 1856) [as *Nassa waldorfensis* (Arnold, 1907)]¹
Diodora aspera (Eschscholtz, 1833)
Discotectonica sp.²
Epitonium cf. *E. tincta* (Carpenter, 1864)
Euspira cf. *E. lewisii* (Gould, 1847)
Fusitriton cf. *F. oregonensis* (Redfield, 1848)
Garnotia adunca (Sowerby, 1825)
Glossaulax reclusianus (Deshayes, 1838)
Hespererato cf. *H. columbella* (Menke, 1847) [? as *E. cf. Erato scabriuscula* Sowerby, 1832]

Hima mendicus (Gould, 1849), small variety [and
H. cooperi (Forbes, 1852), small variety]
Homalopoma cf. *H. luridum* (Dall, 1885) [as *H.*
cf. *H. carpenteri* (Pilsbry, 1889)
Homalopoma cf. *H. paucicostata* (Dall, 1871)
Iselica ovoidea (Gould, 1853) [as *I. fenestrata*
(Carpenter, 1864)]
Lirobuccinum portolaensis (Arnold, 1908)¹
Lirularia cf. *L. optabilis* (Carpenter, 1864)
Megasurcula carpenteriana (Gabb, 1865)
[inflated variety and *M. cf. M. c. tryoniana*
(Gabb, 1866)]
Megathura crenulata (Sowerby, 1825)?
Niveotectura cf. *N. fuciculata* (Carpenter, 1864)
Nucella sp.
Ocenebrina cf. *O. atropurpurea* (Carpenter,
1865) [as *Ocenebra* cf. *O. clathrata* (Dall,
1919)]
Ocenebrina cf. *O. barbarensis* (Gabb, 1865)
Ocenebrina lurida (Middendorff, 1848)
Odostomia cf. *O. farallonensis* Dall and Bartsch,
1909
Opalia varicostata Stearns, 1875 [syn. *Opalia*
varicostata anomala Stearns, 1875]¹
Ophiodermella graciosa Arnold, 1903¹
Perimargelia interfossa (Carpenter, 1864) [as
Mangelia interlirata Stearns, 1864, inflated

variety]
Pomaulax cf. *P. gibberosa* (Dillwyn, 1817)
“*Propebela*” sp.
Psephaea oregonensis (Dall, 1907)¹
Puncturella cooperi asphales Woodring in
Woodring and Bramlette, 1950[1951]¹
Ranella lewisii Carson, 1926¹
Rictaxis cf. *R. punctocaelatus* (Carpenter, 1864)
Selia montereyensis Bartsch, 1907
Serpulorbis squamigerus Carpenter, 1857?
[smooth var.?]
Sinum scopulosum (Conrad, 1849)
Solariella n. sp.
Strioterebrum martini English, 1914¹
Tegula? sp.
Teinostoma cf. *T. supravallata* (Carpenter, 1864)²
Pusula cf. *P. californiana* (Gray, 1827) [? As *P.*
cf. *P. sanguinea* (Sowerby, 1832)]
Turbonilla cf. *T. arnoldi* Dall and Bartsch, 1903
Turbonilla cf. *T. anteslriata* Dall and Bartsch,
1907
Turcica coffea brevis Stewart, in Woodring and
others, 1941 [as *T. imperialis brevis* Stewart,
in Woodring and others, 1941]¹
Turritella cooperi Carpenter, 1864
Turritella hemphilli Merriam, 1941¹
Vitrinella stearnsi Bartsch, 1907

Age – Extinct taxa from the Careaga Sandstone include the bivalve *Arca santamariensis*, *A. sisquocensis*, *Barbatia pseudoillota*, *Crenomytilus* cf. *C. coalingensis* *Cyclocardia californica*, *Lituyapecten dilleri*, *Lyropecten cerrosensis*, *Myrakeenea veatchii*, *Patinopecten healeyi*, *Pecten bellus*, *Petricola* cf. *P. buwaldi*, *Protothaca* cf. *P. staleyi*, *Pycondonte erici*, *Saccella orcutti*, *Solena perrini*, *Swiftopecten parmeleei* s.s., and the gastropods “*Bittium*” *casmaliene*, “*B.*” c. *arnoldi*, *Calicantharus fortis angulata*, *Calliostoma coalingense caloteron*, *C. virgineum*, *C. radians*, *Cancellaria arnoldi*, *C. fergusoni*, *C. hemphilli*, *C. lipara*, *C. rapa*, *C. r. perrini*, *Crepidula princeps*, *Demondia californianus*, *Lirobuccinum portolaensis*, *Opalia varicostata*, *Ophiodermella graciosa*, *Psephaea oregonensis*, *Puncturella cooperi asphales*, *Ranella lewisii*, *Turcica coffea brevis*, and *Turritella hemphilli*. These taxa indicate a Pliocene age for the Cebada fine-grained Member of the Careaga Formation.

Summary

The Pliocene was a period of mostly neutral to cool-water temperatures off the California coast compared to today. The occurrence of warm-water southern extralimital mollusks at several localities in southern and central California is surprising and although these outcrops are poorly dated the occurrence of these warm-water species suggests that these scattered sites might represent a single period of time when temperatures were warmer than today. Therefore, we propose using Pliocene warm water southern extralimital mollusks to recognize this middle Pliocene warm water event in southern California. Collections from the Border locality of the

San Diego Formation, unnamed Pliocene deposits on San Clemente Island and in the Whittier Hills, sediments attributed to the “Santa Barbara” Formation at Rincon Hill/Rincon Road, and the Cebada fine-grained Member of the Careaga Formation all contain warm-water extralimital mollusks and are used here to develop a ecologic based, warm water biostratigraphic unit that is tentatively correlated with the 3.3 to 3.15 Ma mid-Pliocene warm event of Leroy and Dupont (1994) and Tiedemann and others (1994) based on their Pliocene age and the presence of southern extralimital mollusks, especially *Discotectonica*.

Because the above sites/formations cannot be precisely dated they are only tentatively correlated with one another here via their southern extralimital, warm water taxa. Curiously each site has a slightly different suite of extinct species. If these deposits are the same age then one would expect that they would contain the same extinct species. But, these differences possibly reflect differences in the ecological setting of each site/geologic unit. Also the geographic distributions of extinct species are poorly known, so they might have limited geographic distributions. In any case, all the sites/formations discussed above are consistent with a middle Pliocene age based on their mollusk faunas, if not a much broader age range.

As these and other Pliocene sites are better documented and dated a more precise biostratigraphy can be developed and correlated with the International Stratigraphic Chart (<http://www.stratigraphy.org/chus.pdf>; retrieved 12/2008). This method of using the paleotemperatures as an aid to dating mollusk faunas has been successful in the Pleistocene of southern California (see Powell and others, 2000) and extending it to other age deposits and over a broader geographic area is worth pursuing.

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REPORTS OF SOCIETY BUSINESS

EXECUTIVE BOARD MEETING MINUTES - JULY 5, 2008

No minutes could be found

GENERAL MEMBERSHIP MEETING MINUTES - JUNE 7, 2008

- WSM President Charles Powell, II called the meeting to order at 2:16 P.M.
- Other current WSM officers were named:
 - First Vice President: Michael Vendrasco
 - Second Vice President: unofficially George Kennedy
 - In the Executive Board Meeting (June 5, 2008), G. Kennedy was suggested as second vice president
 - He was officially elected in this meeting
 - Third Vice President: Esteban Felix-Pico, who was elected at last year's annual meeting in La Paz, Mexico
 - Treasurer and Secretary: Vic Smith
- C. Powell then mentioned that V. Smith will be stepping down from his current positions, and that no members-at-large were nominated at the Executive Board Meeting
 - G. Kennedy volunteered to be second vice president (president 2010)
 - C. Powell volunteered to be secretary
 - Doug Eernisse suggested Kelvin Barwick as treasurer and he agreed to the position
 - Hans Bertsch and Nora Foster volunteered to be members-at-large
 - A motion was made to accept the slate of officers, seconded, and approved by all
 - No volunteers could be found for the auditing committee
 - The Student Grant committee will be determined at a later date as volunteers are found
 - H. Bertsch volunteered to act as financial intermediary between Mexican and American colleagues. He suggested Mexican members can deposit money directly into his Mexican bank account, or send a check to him that he will deposit in his account, and he will be able to transfer to WSM without transaction fees. H. Bertsch also mentioned that he will send an e-mail to the WSM Treasurer and President upon any such transaction
- C. Powell suggested that Ellen Moore be presented with an Award of Honor, including a lifetime membership in WSM, for her contributions to West Coast molluscan paleontology
 - D. Eernisse and many others seconded simultaneously. Approved by all
- C. Powell then asked First Vice President M. Vendrasco to present details about next years conference
 - M. Vendrasco said he did not know where the conference will be held, and is open to suggestions. Some possibilities mentioned include Asilomar (although many pointed out it is likely too late to book facilities there for this coming year), Santa Barbara Museum of Natural History, and California State University, Fullerton. One attendee suggested the Los Angeles County Museum of Natural

History. M. Vandresco said the conference will most likely be in mid-summer, but is contingent on scheduling of facilities

- M. Vandresco said he will inform everyone once the time and place when it is determined, hopefully within a month or two.
- C. Powell then asked Second Vice President G. Kennedy where the following year's (2010) meeting will be.
 - G. Kennedy said he will need to work this out and perhaps coordinate with the AMS annual meeting.
- Charles then asked Third Vice President Esteban Felix-Pico where the 2011 meeting will be.
 - E. Felix replied that will be in La Paz and the meeting will be combined with the Mexican Malacological Society.
- The topic of student grants was then mentioned, including the question of why there were none this year. The answer being no dues were collected this year and one of the shell clubs from which those funds have been give in the past is not able not able to send funds anymore.
 - Carol Hertz mentioned that the San Diego Shell Club was never approached for funds for this purpose.
 - C. Powell mentioned that that the upcoming President should contact C. Hertz about funding for next year's student grant(s).
- C. Powell mentions that binders (as stated in the Society By-laws) on details of the duties of the WSM officers are missing, as well as the WSM gavel.
 - G. Kennedy says that he initially put together binder but likewise is not sure where it is. If found the contents should be put on the WSM web site.
 - K. Barwick suggests the WSM use the Google group discussion site for executive board and invited guest to communicate Society business. This group would be archived and searchable. K. Barwick agreed to set this up for WSM—he just needs everyone's e-mail address.
 - C. Powell suggested opening up this discussion board to all interested.
 - G. Kennedy said past presidents of WSM as unofficially board members, so should also be included.
 - C. Powell will provide K. Barwick with a list of e-mails.
 - H. Bertsch suggested we put a link to this discussion board on the website.
 - C. Hertz made the motion, H. Bertsch seconded, approved by all.
- C. Powell brought up the issue of annual reports.
 - N. Foster mentioned that Hans is doing the final edit from last year (2007) annual report.
 - H. Bertsch said it is a gratifying experience, but he wants it done faster this year.
 - C. Powell asked for status of the 2005-2006 annual reports.
 - H. Bertsch says the 2005-2006 annual reports are not yet out. Hans said he understood that the last two presidents are supposedly producing these annual reports. Hans reported that he spoke with Roland Anderson (2006 president) on the phone recently about this, but has yet to receive an answer. Nothing has come from 2007 president Peter Roopnarine either.

- G. Kennedy reported that he talked to P. Roopnarine about this in the past week. G. Kennedy also mentions the need to have treasury reports and other important files in addition to abstracts in the annual report. He said to consult bylaws for more detail about what should be included in the annual report.
 - N. Foster mentioned that for 2004 Annual Report there are no treasurer reports or minutes in spite of numerous requests.
 - C. Powell indicated a November 15 deadline for papers and abstracts for this year's meeting
 - G. Kennedy mentions that presenters can expand their abstracts so that the annual report looks better.
 - G. Kennedy said that, for purposes of the annual report, to send him any photos or anything else about WSM that might be well suited for inclusion in the journal. He also said to make sure to list who is in each picture sent to him.
 - C. Powell mentioned that there is a WSM archive at the Santa Barbara Museum of Natural History.
 - Some attendees brought up possible leads for where the WSM gavel might be.
 - Carlos Cáceres Martínez said that he has yet to receive payment for expenses for last year's annual meeting. He says he owes his University about \$870 (U.S.).
 - C. Powell says to send him the exact amount, because he also needs to be reimbursed for expenses for this year's conference, so he can contact V. Smith so that both can be reimbursed.
 - G. Kennedy motions to have C. Cáceres Martínez reimbursed ASAP, many second, approved by all.
 - Then the same vote was made for C. Powell to be reimbursed, and this was likewise approved.
 - C. Cáceres Martínez then asked about how to go about getting more funding for indigenous shell crafters that he described in his Thursday morning (June 5) talk.
 - H. Bertsch said that if anyone wants to make a donation, he will act as conduit for changing American to Mexican funds. His wife donated \$50.
 - C. Hertz said the WSM probably should not donate due to lack of funds, but individuals in the society can make contributions. Most of those in attendance appeared to agree.
 - C. Powell said that a notice about the need for funds for this might be put in the annual report.
 - G. Kennedy reported that at the end of the 2004 meeting, a 5-piece ensemble played, and individual WSM members were moved to finance the recording of a CD of this group's music.
 - A question was then raised on the financial status of WSM.
 - C. Powell mentioned that in ~2004, the WSM had 3 CDs valued at over \$20,000 and about \$2-3,000 in a checking account. No one present had any more recent details.
 - C. Powell reported that the Asilomar meeting (2006) was not in debt.

- D. Eernisse reported that WSM in the past had contributed at least half the funds for student grants.
 - C. Hertz says that there is usually a line on the dues notice for contributions from WSM members for this purpose.
 - C. Powell noted that no dues notices had gone out this year (based on communication from Vic Smith and observations of many members).
 - G. Kennedy mentioned that historically grant offerings are proportional to how well the society is doing financially.
 - Chris Kitting mentioned that many students who receive WSM grants do not attend the annual meetings (one possible reason being the awards do not typically enough to cover travel to the meeting), so he brought up for discussion the possibility of combining the grant with the best paper award, to ensure that money goes to students who actually contribute to WSM.
 - This initiated another discussion on WSM funds. D. Eernisse suggested Terry Gosliner might be able to lean on V. Smith to divulge amount of funds so that action can be taken for WSM grants for this coming year.
 - C. Hertz mentioned the need for a committee to determine who should get student grants.
 - H. Bertsch suggested setting up a planning committee before the final grant committee is set up.
 - Janet Leonard moved that when C. Powell gets in touch with V. Smith, he can also get an update on funds.
 - C. Cáceres Martínez mentioned that V. Smith has not yet answered his requests for reimbursement.
 - D. Eernisse mentioned that we cannot post a grant notice until all board members discuss this issue.
 - K. Barwick mentioned the need to know how much money WSM has before any further serious discussion of student grants can take place.
 - C. Kitting reiterated for discussion the proposal to combine best presentation award with student grants.
 - D. Eernisse agreed that student grants should be larger, but he and others disagreed with the proposal to combine these two awards, so this issue was dropped for the time.
 - C. Kitting said he would donate \$100 for the best student award, and C. Powell said he would donate an extra \$20 for the 2008 meeting
 - Orso Angulo was proposed as best student presenter this year, and all were in favor.
 - H. Bertsch said to give money for this purpose and/or for donation to the indigenous shell-crafters that C. Cáceres Martínez is working with and he will transfer funds to both and provide a list of all donors.
 - D. Eernisse mentioned that the *Unitas* and *AMS Newsletter* are good places where the WSM can advertise grants.
 - C. Hertz and C. Kitting mentioned that we should give WSM grants to people that we judge will most likely attend future meetings.

- C. Cáceres Martínez mentioned the need to have the treasurer make sure all dues are paid.
- C. Powell suggested that WSM send out an annual report along with the dues notice, as a way to entice previous but currently non-active members to rejoin, in that way building WSM funds.
 - G. Kennedy moved to send out a copy of the annual report with the upcoming dues notice, J. Leonard seconded, and approved by all.
- C. Hertz and C. Kitting agreed to start the committee to begin work on student grants. H. Bertsch said a group of three should do this and send off to the proper specialists within the WSM. C. Powell volunteered to review submissions relating to paleontology, N. Foster will volunteer to review grants related to archeology.
- G. Kennedy moves to adjourn the meeting, C. Kitting seconds, and all approve.

Minutes recorded by Michael Vendrasco, 6/7/2008; edited by C. Powell and others via email, 6/10-12/2008.

It should be noted that Vic Smith showed up after the meeting and wrote a check for Carlos Cáceres Martínez (2007 President). The 2008 meeting hadn't concluded so reimbursement of those funds will wait until the bookkeeping has been done.

GROUP PHOTOGRAPH



Front row (left to right): Charles Powell, Ashley Fore, Eric Gonzales, Laney Whitlow, Albert Rodrigues, Elizabeth Moore, Carlos Cáceres Martines with Juliana Cáceres Barnios, and Daniela Branos Ruiz.

Second row (left to right): Raed El Hajjaoui, Vicky H. Lee, Patty Jo Hoff, Clay Carson, Neil Fahy, Marta Pola, Hans Bertsch, Rosa Campay, Jan Leonard.

Back row (left to right): Doug Eenisse, Michael Vendrasco, Esteban Felix Pico, Orso Angulo, Patrick I. LaFollette, Kelvin Barwick, Chris Kitting, Carole Hertz, Jules Hertz, Nora Foster, Terry Gosliner, George Kennedy.

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